NEMA STANDARDS PUBLICATION NO. ICS 2

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Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated Not More Than 2000 Volts AC or 750 Volts DC

NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037

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NEMA Standards Publication No. ICS 2-1993

INDUSTRIAL CONTROL AND SYSTEMS
CONTROLLERS, CONTACTORS, AND OVERLOAD RELAYS RATED NOT MORE THAN 2000 VOLTS AC OR 750 VOLTS DC

Published by:

National Electrical Manufacturers Association
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FOREWORD

This Standards Publication was prepared by a technical committee of the NEMA Industrial Control and Systems Section. It was approved in accordance with the bylaws of NEMA and supersedes the indicated NEMA Standards Publication.

Replacement: The first seven parts of ICS 2-1993 supersede the following parts of ICS 2-1988:
Part 1 supersedes ICS 2-110 and ICS 2-210.
Part 2 supersedes ICS 2-321 and ICS 2-327.
Part 3 supersedes ICS 2-328 and ICS 2-329.
Part 4 supersedes ICS 2-222.
Part 5 supersedes ICS 2-331.
Part 6 supersedes ICS 2-448 and ICS 2-449.
Part 7 supersedes ICS 2-211.
Annex A of ICS 2 supersedes ICS 2-302 of ICS 2-1988 and NEMA Standards Publication No. ICS 2.2.

In 1988, unrevised portions of all NEMA Standards Publications for Industrial Controls and Systems (the ICS series) were reaffirmed.

This Standards Publication provides practical information concerning ratings, construction, test, performance and manufacture of industrial control equipment. These standards are used by the electrical industry to provide guidelines for the manufacture and proper application of reliable products and equipment and to promote the benefits of repetitive manufacturing and widespread product availability.

NEMA Standards represent the result of many years of research, investigation and experience by the members of NEMA, its predecessors, its Sections and Committees. They have been developed through continuing consultation among manufacturers, users and national engineering societies and have resulted in improved serviceability of electrical products with economies to manufacturers and users.

One of the primary purposes of this Standards Publication is to encourage the production of reliable control equipment which, in itself, functions in accordance with these accepted standards. Some portions of these standards, such as electrical spacings and interrupting ratings, have a direct bearing on safety; almost all of the items in this publication, when applied properly, contribute to safety in one way or another.

Properly constructed industrial control equipment is, however, only one factor in minimizing the hazards which may be associated with the use of electricity. The reduction of hazard involves the joint efforts of the various equipment manufacturers, the system designer, the installer and the user. Information is provided herein to assist users and others in the proper selection of control equipment.

The industrial control manufacturer has limited or no control over the following factors which are vital to a safe installation:

a. Environmental conditions
b. System design
c. Equipment selection and application
d. Installation
e. Operating practices
f. Maintenance

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This publication is not intended to instruct the user of control equipment with regard to these factors except insofar as suitable equipment to meet needs can be recognized in this publication and some application guidance is given.

This Standards Publication is necessarily confined to defining the construction requirements for industrial control equipment and to providing recommendations for proper selection for use under normal or certain specific conditions. Since any piece of industrial control equipment can be installed, operated and maintained in such a manner that hazardous conditions may result, conformance with this publication does not by itself assure a safe installation. When, however, equipment conforming with these standards is properly selected and is installed in accordance with the National Electrical Code and properly maintained, the hazards to persons and property will be reduced.

To continue to serve the best interests of users of Industrial Control and Systems equipment, the Industrial Control and Systems Section is actively cooperating with other standardization organizations in the development of simple and more universal metrology practices. In this publication, the U.S. customary units are gradually being supplemented by those of the modernized metric system known as the International Systems of Units (SI). This transition involves no changes in standard dimensions, tolerances, or performance specifications.

NEMA Standards Publications are subject to periodic review. They are revised frequently to reflect user input and to meet changing conditions and technical progress. Users should secure the latest editions. See the postal return card attached to the front cover of the Standards Publication for the proper procedure to obtain revision service for your copy of the publication.

Proposed revisions to this Standards Publication should be submitted:

Vice President Engineering
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INTRODUCTION

The standards pertaining to controllers, contractors, and overload relays in NEMA Standards Publication ICS 2 are subdivided into the following clauses:

1 General
  Referenced Standards
  Scope
  Normative References
2 Definitions
  Terms which supplement the IEEE Standard Dictionary of Electrical and Electronics Terms (Std 100) or assist in clarifying the product standard.
3 Classification
  Product classifications where they have been established.
4 Characteristics and Ratings
  Descriptions of the kinds of ratings applicable to the product and tables of standard ratings for the product where they have been established.
5 Product Marking, Installation and Maintenance Information
  Product information to be provided to assist the user in the installation, use and maintenance of the devices.
6 Service and Storage Conditions
  A description of service and storage conditions for which the devices are intended.

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7 Construction
Marking, color coding and similar production requirements to be incorporated into the product as manufactured, as well as production test requirements where they have been established, i.e., the rules that the manufacturer follows in producing the product.

8 Performance Requirements and Tests
The performance required to pass each design test specified for the product.

9 Application
Information and performance considerations of importance to those who specify or use the product.

The standards for the products included within the scope of the Industrial Control and Systems Section are organized as follows:

NEMA Standards Title
Publication No.

ICS 1-1993 Industrial Control and Systems
General Requirements

ICS 2-1993 Industrial Control and Systems
Controllers, Contactors, and Overload Relays, Rated Not More Than 2000 Volts AC or 750 Volts DC.

Part 1: *General Standards for Manual and Magnetic Controllers*
Part 2: *AC Noncombination Magnetic Motor Controllers, Rated 600 Volts*
Part 3: *Nonmagnetic Motor Controllers*
Part 4: *Overload Relays*
Part 5: *DC General-Purpose Constant-Voltage Controllers*
Part 6: *AC Combination Motor Controllers*
Part 7: *Magnetic Lighting Contactors*

ICS 3-1993 Industrial Control and Systems
Factory-built Assemblies

Part 1: *Motor Control Centers Rated Not More Than 600 Volts AC*
Part 2: *Medium Voltage Controllers Rated 2001 to 7200 Volts AC*
Part 3: *AC General-Purpose Controllers for Synchronous Motors*

ICS 4-1993 Industrial Control and Systems
Terminal Blocks

ICS 5-1993 Industrial Control and Systems
Control Circuit and Pilot Devices

Part 1: *General Standards for Control Circuit and Pilot Devices*
Part 2: *Industrial Control Relays*
Part 3: *Industrial Control Input Devices Actuated by Force, Temperature and Pressure*
Part 4: *Proximity Switches*
Part 5: *Pushbuttons, Selector Switches, Indicating Lights and Pushbutton Stations*

ICS 6-1993 Industrial Control and Systems
Enclosures

ICS 7-1993 Industrial Control and Systems
Adjustable Speed Drives

Part 1: *General Standards for Drive Converters, Drives, and Drive Systems*
Part 2: *Loop Position and Tension Control Drive Systems*
Part 3: *Wind and Unwind Drive Systems*
Part 4: *Variable-Frequency, Three-Phase Controllers, Rated Not More Than 600 Volts*
Part 5: *Adjustable-Voltage Packaged-Drive Systems (Where DC Armature Power Is Obtained from AC Lines Using Controlled Semiconductor Rectifiers)*

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Part 6: *Variable-Frequency Drive Systems Rated Not More Than 600 Volts Using Semiconductor Power Conversion*
Part 7: *Variable-Frequency Three-Phase Drives, Rated 601 to 7200 Volts*

ICS 8-1993 Industrial Control and Systems
Crane and Hoist Controllers

Part 1: *General Standards for Crane Controllers Rated 600 Volts or Less AC and DC*
Part 2: *Constant-Voltage DC Magnetic Controllers for Motors on Cranes*
Part 3: *Adjustable-Voltage DC Controllers for Motors on Cranes*
Part 4: *Magnetic Controllers for AC Wound-Rotor Motors on Cranes*
Part 5: *Static Controllers for AC Wound-Rotor Motors on Cranes*
Part 6: *Crane and Hoist Power-Circuit Limit Switches*
Part 7: *Heavy-Duty DC Magnetic Contactors Rated 600 Volts*

ICS 9-1993 Industrial Control and Systems
Power-Circuit Accessories

Part 1: *Electromagnetic Brakes*
Part 2: *Resistors and Rheostats*
Part 3: *Autotransformers and Reactors*

ICS 10-1993 Industrial Control and Systems
AC Transfer Switch Equipment

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Part 1
GENERAL STANDARDS FOR MANUAL AND MAGNETIC CONTROLLERS

1 General

1.1 Referenced Standards

The following standards contain provision which, through reference in this text, constitute provisions of this NEMA Standard Publication. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

American National Standards Institute
11 West 42nd Street
New York, NY 10036

C37.90-1978	*Relays and Relay Systems Associated with Electrical Power Apparatus*

U.S. Government Printing Office
Mail Stop: SSOP,
Washington, DC 20402-9328

Code of Federal Regulations	*Occupational Safety and Health Standards (OSHA)*
29 CFR 1910.147	*Control of Hazardous Energy Sources (Lockout/Tagout)*
29CFR 1910.331-335	*Safety Related Work Practices*

National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, DC 20037

AB 1-1986	*Molded Case Circuit Breakers*
ICS 1-1993	*Industrial Control and Systems General Requirements*
ICS 1.3-1986	*Preventive Maintenance of Industrial Control and Systems Equipment*
ICS 6-1993	*Enclosures for Industrial Control and Systems*
MG 2-1989	*Safety Standard for Construction and Guide for Selection, Installation, and Use of Electric Motors and Generators*

Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook, IL 60062

ANSI/UL 508-1993	*Industrial Control Equipment (16th Edition)*

1.2 Scope

The standards in this part apply to power circuit devices covered in all other parts in ICS 2 pertaining to power circuit devices unless otherwise specified.

1.3 Normative References

The definitions and standards of NEMA Standards Publication ICS 1 also apply to this part unless otherwise stated.

2 Definitions

For the purposes of this standard, the following definitions apply:

short-time operating capability: The ability of a motor controller with its contacts closed, to withstand the thermal stresses due to starting and accelerating a motor to normal speed and those due to an operating overload.

short-time surge capability: The ability of a motor controller with its contacts closed, to withstand the thermal and mechanical stresses due to current surges, such as might result from restoration of power to the load following a momentary loss of power.

3 Classification of Manual and Magnetic Controllers

Controllers shall be designated as Class A, B, or V in accordance with the interrupting medium and their ability to interrupt currents.

These controllers are designed for interrupting operating overloads only. For definition of operating overload, see NEMA Standards Publication ICS 1.

In general, manual controllers are limited to 600 volts or less. A controller may be a combination of manually and magnetically operated components.

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3.1 Class A Controllers

Class A controllers are alternating current air-break, vacuum-break or oil-immersed manual or magnetic controllers for service on 600 volts or less. They are capable of interrupting operating overloads but not short circuits or faults beyond operating overloads. For standards applying to these controllers, see Parts 2, 3 and 6.

3.2 Class B Controllers

Class B controllers are direct current air-break manual or magnetic controllers for service on 600 volts or less. They are capable of interrupting operating overloads but not short circuits or faults beyond operating overloads. For standards applying to these controllers, see Part 5.

3.3 Class V Controllers

Class V controllers are alternating current vacuum-break magnetic controllers for service on 1500 volts or less, and capable of interrupting operating overloads but not short circuits or faults beyond operating overloads.

4 Characteristics and Ratings

See product parts of this publication for characteristics and ratings.

5 Product Marking, Installation and Maintenance Information

5.1 Maintenance

See NEMA Standards Publication ICS 1.3 for preventive maintenance instructions.

5.2 Marking

Where the mark NEMA is shown on a magnetic or manual contactor or controller, or appears on any supportive material supplied with that device, the product shall comply with all of the ratings for that device as defined in the standard for that device.

Where a device is marked with a NEMA size designation, a marking shall include, at a minimum, all of the 60 hertz horsepower ratings for that device as given in the single-phase or three-phase, nonplugging and nonjogging duty rating table.

The manufacturer shall be permitted to mark additional ratings for that size provided that only those ratings specified in the appropriate NEMA product standard for that size are used.

References to standards other than NEMA, on products carrying the "NEMA" mark are permitted, provided that all ratings referencing such standards are identical to those marked as the NEMA ratings and provided that the product complies with all ratings for that device, as defined in the NEMA standard for that device.

6 Service and Storage Conditions

See ICS 1, Part 6.

7 Construction

7.1 Sizes of Terminals for External Power Connections

Manual and magnetic controllers shall have terminals suitable for connection to external copper conductors, shown in Table 1-7-1, the insulation of which is rated either 60° or 75°.

Note: The maximum wire size shown is for a 40°C ambient based on the ampacity required for service-limit current corresponding to the controller size. The minimum wire size shown is for 75°C insulation in a 30°C ambient and minimum motor full-load current corresponding to horsepower.

7.2 Mechanical Interlocking of Manual and Magnetic Contactors

Contactors which would cause a line-to-line fault if they are in the closed position at the same time shall be mechanically interlocked to prevent this condition.

7.3 Electrical Interlocking of Magnetic Contactors

Two or more magnetic contactors which would cause a line-to-line fault if they were in the closed position at the same time shall be electrically interlocked by means of normally-closed auxiliary contacts connected in series with their coils.

8 Performance Requirements and Tests

8.1 Make and Break Design Test

The make and break design test for Class A manual and magnetic motor controllers shall be 10 times the rated motor full-load current (MFLC) for 10 operations in a single continuous test, without intervening maintenance or servicing, at a maximum rate of one operation per minute with a minimum "ON" time of 0.1 second. Ten times MFLC is not a rating.

In performing the above test, a new motor controller shall be used with a motor or a simulated motor load consisting of resistors in series with air-core reactor(s) for each phase. The air-core reactors shall not be connected in parallel with any other resistors or reactors, except that the reactor(s) in each phase may be shunted by a resistor having a power loss of approximately one percent of the total power consumption of the phase. This test shall be made at rated voltage and a power factor of 40 to 50 percent.

8.2 Range of Coil Operating Voltage

8.2.1 Contactors with DC Coils

Contactors with DC coils shall withstand 110 percent of their rated voltage continuously without injury to the operating coils and shall close successfully at 80 percent of their rated voltage.

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Table 1-7-1
TERMINALS

Size of Controller	Minimum Range of Conductor Sizes* (One Conductor Per Terminal Unless Otherwise Stated) For Conductor Insulation Rated 60°C	For Conductor Insulation Rated 75°C
00	14 AWG	14 AWG
0	14-10 AWG	14-10 AWG
1	14-8 AWG	14-8 AWG
1P	8-6 AWG	10-8 AWG
2	10-4 AWG	10-6 AWG
3	8-1/0 AWG	10-1 AWG
4		4-3/0 AWG
5		2/0 AWG-500 kcmil
6		Two 2/0 AWG-Two 500 kcmil
7		Three 2/0 AWG-Three 500 kcmil
8		Four 2/0 AWG-Four 500 kcmil
9**		

*For controller size 5 and larger, a combination of parallel conductors that provide ampacity equivalent to the wire sizes shown shall be permitted.
**Busbar or cable-connected, as specified between control manufacturer and user.

8.2.2 Contactors with AC Coils

Contactors with AC coils shall withstand 110 percent of their rated voltage continuously without injury to the operating coils and shall close successfully at 85 percent of their rated voltage.

Where the coil of a controller is operated from the secondary of a control-circuit transformer having its primary connected to the supply circuit of the controller, the controller shall withstand 110 percent of its rated voltage without injury to the operating coil and shall operate successfully at 90 percent of the rated voltage of the supply circuit. See ICS 1, Clause 8.

8.3 Short-Time Capability Tests

Separate tests shall be conducted to establish short-time operating capability and short-time surge capability. The test current shall be passed through the closed contacts for the specified period of time, and must be supplied at a voltage sufficient to maintain the current. At the end of the tests:

a. The motor controller must be capable of withstanding the dielectric tests described in ICS 1, Clause 8.
b. The contacts must be capable of being opened by normal operation.

A separate source of power may be supplied to the coils of magnetically operated devices.

8.4 Temperature Rise Test of Coils and Current-Carrying Parts

The temperature rise of the coils and current-carrying parts of contactors and controllers shall be measured simultaneously when tested in accordance with their ratings. The values shall not exceed those given in ICS 1, Clause 8.

9 Application

9.1 The I^2t value (Joule Integral) calculated from the surge capability test cannot be used to estimate the performance of the contactor under short-circuit conditions.

9.2 Control-Circuit Transformers

Transformers used to provide control-circuit voltage to magnetic controllers are known as machine-tool transformers in NEMA Standards Publications.

9.2.1 Transformers used with magnetic controllers shall meet the following requirements:

a. The rated primary voltage of the transformer shall be equal to the system voltage.

Exception: Transformers with a higher voltage rating than the system voltage shall be permitted to be used, but only if the following calculation results in a value of control voltage equal to the rated control voltage of the controller.

$$\text{System Voltage} \times \frac{\text{Rated Transformer Secondary Voltage}}{\text{Rated Transformer Primary Voltage}} = \text{Rated Control Circuit}$$

b. The rated secondary voltage of the transformer shall be equal to the rated control-circuit voltage of the controller.

9.2.2 The size and design of the transformer shall be such as to limit the amount the secondary voltage vari-

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ations above and below the rated control-circuit voltage, under conditions of minimum and maximum currents, as defined below.

a. At Minimum Current

With rated primary voltage and frequency applied to the transformer, and with the sealed current of a single load, or the sealed or continuous current of the lightest load that may occur with a multiplicity of loads, the secondary voltage shall not be greater than 105 percent of the rated control-circuit voltage.

This condition is satisfied if the open-circuit secondary voltage does not exceed 105 percent of rated secondary voltage, with rated primary voltage and frequency applied to the transformer.

b. At Maximum Current (Peak Inrush)

The effective impedance of the transformer shall be such that, with rated voltage and frequency applied to the transformer and with a load impedance corresponding to the power factor and maximum value of the load current connected to the secondary, the voltage at the secondary terminals shall not be less than 95 percent of the rated voltage of the operating coils.

This condition assures compliance with this part where individual contactors which close successfully at 85 percent of rated voltage applied directly to the contactor coil will, when operated from the secondary of a transformer, close successfully at 90 percent of rated transformer primary voltage.

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Part 2
AC NONCOMBINATION MAGNETIC MOTOR CONTROLLERS RATED 600 VOLTS

1 General

1.1 Scope

The standards in this part apply to Class A noncombination magnetic controllers for squirrel cage and wound-rotor induction motors rated in horsepower and in full-load and locked-rotor currents for application at 600 volts and less, 50 and 60 hertz. The contactor portion of these controllers may also be used to control nonmotor loads.

1.2 Normative References

The definitions and standards of NEMA Standards Publications No. 250, ICS 1 and ICS 2, Part 1 apply to this part unless otherwise stated.

2 Definitions

There are no definitions unique to this part.

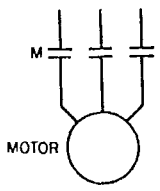
3 Classification

3.1 Classification by Starting Methods

Motor controllers are classified as either full-voltage or reduced-voltage starting. Typical methods of controlling motors areshown in Figures 2-3-1 through 2-3-7. An "x" in the contactor sequence chart indicates closed contacts. The starting current values for the various methods of motor starting may be determined as shown below.

3.2 Full-Voltage Controllers

The starting current for full-voltage controllers is equal to the locked-rotor current at full voltage; see Figure 2-3-1.



CONTACTOR SEQUENCE	
CONTACTOR	START AND RUN
M	X

Figure 2-3-1
FULL VOLTAGE CONTROLLER

3.3 Part-Winding Controllers

Part-winding controllers first connect a part of the motor winding to the supply lines as the first starting step and then connect the remaining portion of the winding to the supply lines as the second step. Part-winding controllers are classified as either full-voltage or reduced-voltage type, the reduced voltage being obtained by the use of a resistor or reactor connected in series with the first-mentioned portion of the winding.

3.3.1 Full-Voltage Part-Winding Controllers

Enclosed, limited plugging and jogging-duty, full-voltage controllers for motors suitable for part-winding starting, shall consist of:

a. A magnetic contactor used to connect one part of the motor winding to the supply lines.
b. A magnetic contactor used to connect a second part of the motor winding to the supply lines.
c. Means to delay the closing of the second contactor.
d. Running overcurrent protection for each motor winding unless equivalent protection is otherwise provided for the motor, the motor control apparatus and the branch-circuit conductors against excessive heating due to motor overloads.
e. Provision for separately mounted control pushbuttons.

With full-voltage part-winding starting (Figure 2-3-2), the starting current is the locked-rotor current of the first winding connected for starting.

3.3.2 Pole Arrangements for Part-Winding Controllers

For one-half winding starting of motors having equal windings that are wye connected with either six or nine leads brought out and for motors that are delta connected with six leads brought out, the controller shall have either a three-pole contactor for the first part of the winding and another three-pole contactor for the second part, or a four-pole contactor for the first part of the winding and a two-pole contactor for the second part.

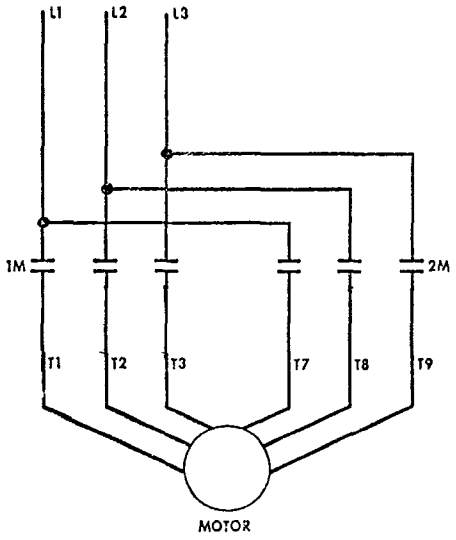
For two-thirds winding starting of motors having equal windings that are wye connected with either six or nine leads brought out and for motors that are delta connected with either six or nine leads brought out, the controller shall have a four-pole contactor for the first part of the winding and a two-pole contactor for the second part.

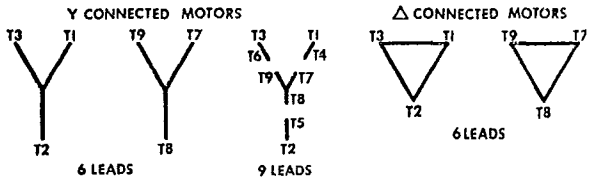
3.4 Full-Voltage Two-Speed Motor Controllers

A single-winding two-speed motor carries current in various configurations of wye and delta to provide either

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THREE POLE—THREE POLE

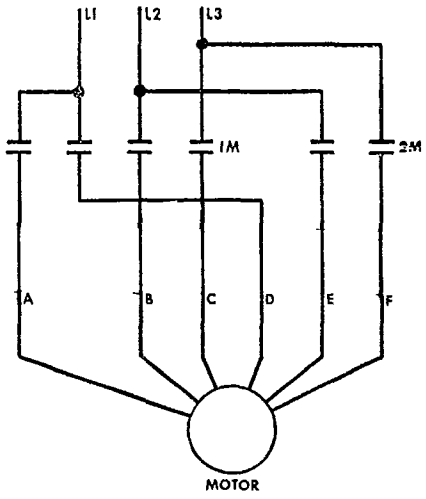




CONNECT MOTOR TERMINALS TO CONTROLLER TERMINALS HAVING THE SAME MARKING (FOR EXAMPLE T1 TO T1).

FOR 9-LEAD Y-CONNECTED MOTORS, CONNECT TERMINALS T4, T5 AND T6 TOGETHER AT THE MOTOR TERMINAL BOX.

FOUR POLE—TWO POLE



—TABLE OF MOTOR LEAD CONNECTIONS—

PART WINDING SCHEMES	LETTERED TERMINALS IN PANEL					
	A	B	C	D	E	F
1/2 Y OR Δ 6 LEADS	T1	T2	T3	T7	T8	T9
1/2 Y 9 LEADS ◊	T1	T2	T3	T7	T8	T9
1/2 Δ 9 LEADS □	T1	T8	T3	T6	T2	T9
2/3 Y OR Δ 6 LEADS	T1	T2	T9	T7	T8	T3
2/3 Y 9 LEADS ◊	T1	T2	T9	T7	T8	T3
2/3 Δ 9 LEADS □	T1	T4	T9	T6	T2	T3

◊ CONNECT TERMINALS 4, 5 AND 6 TOGETHER AT TERMINAL BOX

□ CONNECT TERMINALS 4 AND 8, 5 AND 9, 6 AND 7 TOGETHER IN THREE SEPARATE PAIRS AT TERMINAL BOX.

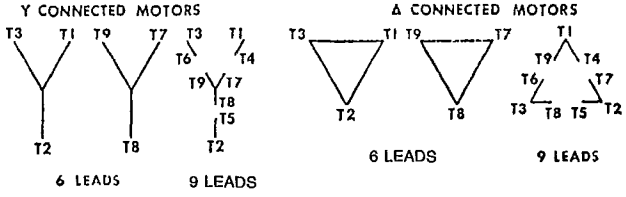


Figure 2-3-2
FULL VOLTAGE PART WINDING CONTROLLERS

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constant torque, variable torque, or constant horsepower at each speed. A two-winding two-speed motor carries current in only one of its windings at each speed. Each winding may be either a wye or delta configuration. To preclude short-circuit current being induced in an unused delta winding, motor controllers used with two-winding motors having one or more delta connections are constructed to open one corner of each delta winding not in the circuit.

NOTE: When controllers are to be supplied for more than two speeds, NEMA Standards Publication MG 1 (1993) should be consulted.

Motor connections for two-speed motor controllers shall be in accordance with Figures 2-3-3 and 2-3-4 for two-winding and single-winding motors, respectively.

3.5 Reduced-Voltage Controllers

Typical forms of reduced-voltage controllers are:

a. reactor or resistor
b. wye-delta
c. part-winding
d. autotransformer

3.5.1 Reactor or Resistor Reduced-Voltage Starting

With reactor or resistor starting (Figure 2-3-5), the starting current is determined from the phasor sum of the impedances of the starting reactor or resistor and of the motor under locked-rotor conditions.

3.5.2 Wye-Delta Controllers

Wye-delta controllers connect the phase windings first in wye relationship for the effect of reduced-voltage starting and, subsequently, reconnect these phase windings in delta relationship for running. The types of wye-delta controllers for induction motors shall be: open-circuit transition or closed-circuit transition.

With wye-delta starting (Figure 2-3-6), the starting current on the wye connection is equal to 0.33 times the locked-rotor current on the delta connection.

3.5.2.1 Open-Circuit Transition

These are enclosed, nonplugging, nonjogging controllers for the effect of reduced-voltage starting of motors by the open-circuit-transition method, consisting of:

a. Two three-pole magnetic contactors, 1M and 2M, for the line connections to the motor
b. One two-pole magnetic contactor, S, where the S contactor is the same size as the 1M and 2M contactors, or a three-pole contactor where the S contactor is one size smaller than the 1M and 2M contactors for the wye neutral connection
c. One means (timing) for maintaining the wye (starting) connection for a predetermined accelerating time
d. One set of mechanical and electrical interlocks to prevent closing 2M before S opens
e. Three overload units,* one in each phase winding, unless equivalent protection is otherwise provided for the motor, the motor control apparatus and the branch-circuit conductors against excessive heating due to motor overloads
f. Provision for separately mounted control pushbuttons

* Phase current is 0.577 times the line current.

3.5.2.2 Closed-Circuit Transition

These are enclosed, nonplugging and nonjogging controllers for the effect of reduced-voltage starting of motors by the closed-circuit-transition method, consisting of:

a. Two three-pole magnetic contactors, 1M and 2M, for the line connections to the motor
b. One two-pole magnetic contactor, 1S, where the 1S contactor is the same size as the 1M and 2M contactors, or a three-pole contactor where the 1S contactor is one size smaller than the 1M and 2M contactors for the wye neutral connection
c. One three-pole magnetic contactor, 2S, for the transition resistor connections
d. One transition resistor for each phase
e. One means (timing) for maintaining the wye (starting) connection for a predetermined accelerating time
f. One set of mechanical and electrical interlocks to prevent closing 2M before 1S opens
g. Three overload units,* one in each phase winding, unless equivalent protection is otherwise provided for the motor, the motor control apparatus and the branch-circuit conductors against excessive heating due to motor overloads
h. Provision for separately mounted control pushbuttons

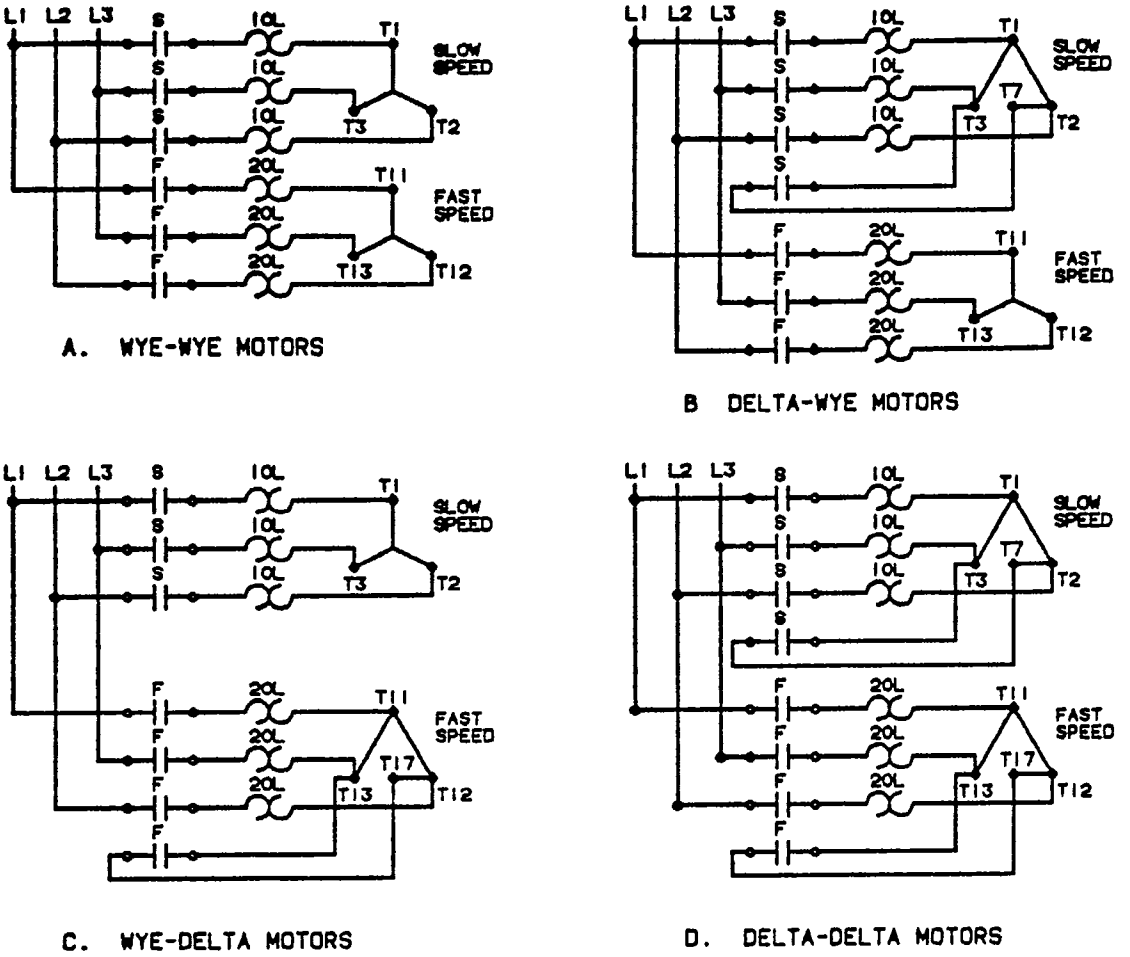
* Phase current is 0.577 times the line current.

3.5.3 Reduced-Voltage Part-Winding Controllers

These are enclosed, limited plugging and jogging, reduced-voltage controllers for motors suitable for part-winding starting, consisting of:

a. A magnetic contactor used to connect one part of the motor winding to the supply lines
b. A resistor or reactor connected into the circuit of this motor winding
c. A magnetic contactor used to short-circuit the resistor or reactor
d. A magnetic contactor used to connect a second part of the motor winding to the supply lines
e. Means to delay the closing of the contactors covered in items c. and d. above
f. Running overcurrent (overload) protection for each motor winding, unless equivalent protection is otherwise provided for protecting the motor, the motor

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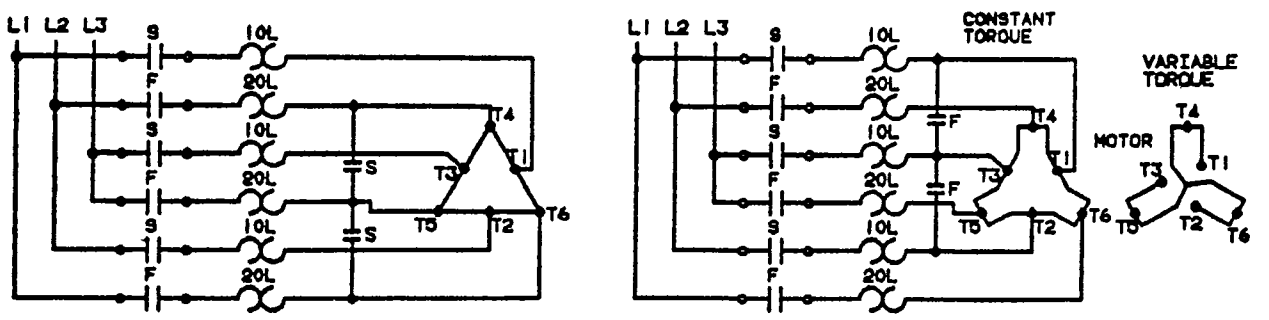
A. WYE-WYE MOTORS

B DELTA-WYE MOTORS

C. WYE-DELTA MOTORS

D. DELTA-DELTA MOTORS

Figure 2-3-3
CONTROLLERS FOR TWO-WINDING TWO-SPEED MOTORS



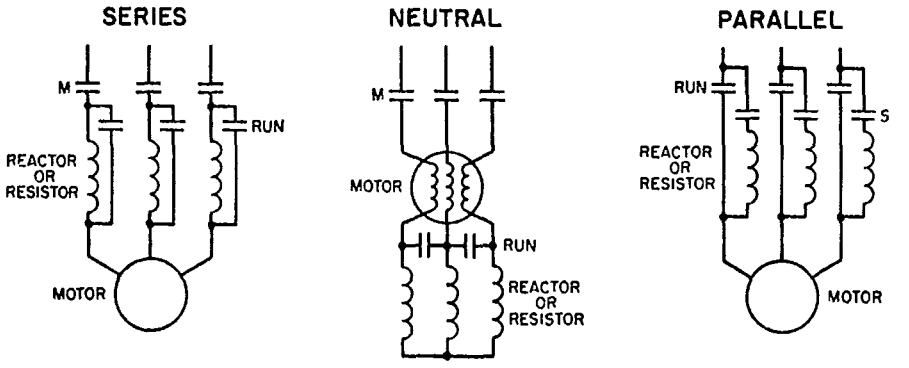
A. CONSTANT HORSEPOWER MOTORS

B. CONSTANT AND VARIABLE TORQUE MOTORS

Figure 2-3-4
CONTROLLERS FOR SINGLE-WINDING TWO-SPEED MOTORS

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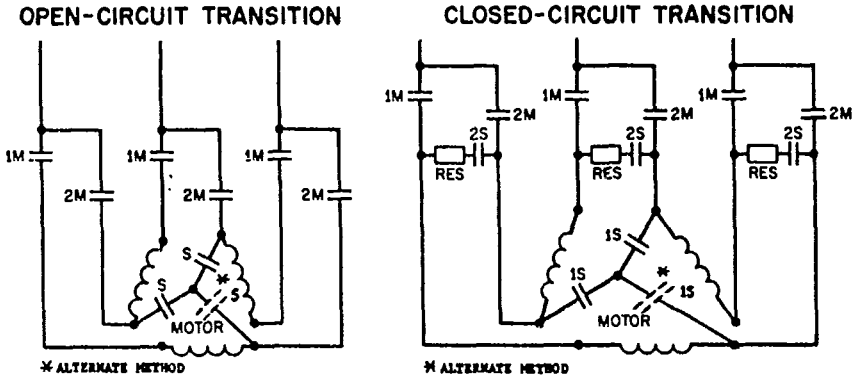
CONTACTOR SEQUENCE		
CONTACTOR	START	RUN
M	X	X
RUN		X

CONTACTOR SEQUENCE		
CONTACTOR	START	RUN
M	X	X
RUN		X

CONTACTOR SEQUENCE			
CONTACTOR	START	TRANSITION	RUN
S	X	X	X*
RUN		X	X

* OPEN OR CLOSED

Figure 2-3-5
REDUCED VOLTAGE CONTROLLER—REACTOR OR RESISTOR



CONTACTOR SEQUENCE				
CONTACTOR	START		TRANSITION	RUN
1M		X	X	X
2M				X
S	X			

CONTACTOR SEQUENCE						
CONTACTOR	START		TRANSITION			RUN
			1	2	3	
1M		X	X	X	X	X
2M					X	X
1S	X		X			
2S			X	X	X	

Figure 2-3-6
WYE-DELTA CONTROLLERS

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control apparatus and the branch-circuit conductors against excessive heating due to motor overloads

g. Provision for separately mounted control pushbuttons

3.5.4 Reduced-Voltage Autotransformer Controllers

These are enclosed, nonplugging nonjogging reduced-voltage controllers, where the reduced voltage is provided by a three-coil or two-coil autotransformer. The autotransformer controllers shall be open-circuit transition or closed-circuit transition.

With reduced-voltage autotransformer starting (Figure 2-3-7), the starting current is determined as follows:

a. The starting current drawn from line = $I \times p^2 + 0.25\ I_m$.
b. The starting current taken by the motor = $I \times p$.
c. The autotransformer neutral current = $I \times p - (I \times p^2 + 0.25\ I_m)$.

Where:

I =Locked-rotor amperes at full voltage
p =Transformer tap used (fraction of full voltage)
I_m =Rated full-load current of motor. The term "0.25 Im" is introduced to allow for transformer magnetizing current

4 Characteristics and Ratings

4.1 Horsepower and Current Ratings

4.1.1 Continuous Current Ratings

Continuous current ratings represent the maximum rms current, in amperes, which the controller shall be permitted to carry continuously without exceeding the temperature rises permitted by ICS 1, Clause 8.

4.1.2 Service-Limit Current Ratings

The service-limit current ratings represent the maximum rms current, in amperes, which the controller shall be permitted to carry for protracted periods in normal service. At service-limit current ratings, temperature rises shall be permitted to exceed those obtained by testing the controller at its continuous current rating. The current rating of overload relays or trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

4.1.3 Basis of Horsepower and Current Ratings

The horsepower and current ratings of AC general-purpose controllers are based on the use of three-pole primary contactors for two- and three-phase motors and of two-pole primary contactors for single-phase motors.

4.1.4 Ratings of Full-Voltage Single-Speed Magnetic Controllers for Limited Plugging and Jogging Duty

The ratings of full-voltage magnetic controllers for limited plugging and jogging, reversing and nonreversing, duty shall be:

a. In accordance with Table 2-4-1 for three-phase controllers.
b. In accordance with Table 2-4-2 for single-phase controllers.

These ratings shall be permitted to be used for occasional jogging or plugging for limited time periods, such as machine set-ups. During such limited time periods, the rate of operation shall not exceed five openings or closings per minute and shall be not more than ten in a 10-minute period.

For duties exceeding the foregoing, see 4.1.5.

These controllers shall not be used with motors whose full-load current, locked-rotor current, or horsepower rating exceeds the values given in Tables 2-4-1 and 2-4-2. The current rating of overload relays or the trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

The full-load current, locked-rotor current or horsepower ratings of two-phase four-wire and two-phase three-wire controllers shall be the same as those shown in Table 2-4-1 for three-phase controllers. Controllers used in two-phase three-wire circuits shall be applied on the basis of the average of the currents in the three legs of the two-phase circuit.

4.1.5 Ratings of Full-Voltage Single-Speed Magnetic Controllers for Plug-Stop, Plug-Reverse or Jogging Duty

The rating of full-voltage magnetic controllers for plug-stop, plug-reverse, and jogging duty requiring repeated interruption of stalled motor current or repeated closing of high transient currents encountered in rapid motor reversal beyond that described in 4.1.4 shall be in accordance with:

a. Table 2-4-3 for three-phase controllers
b. Table 2-4-4 for single-phase controllers

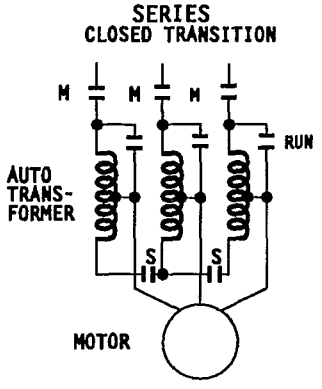
These controllers shall not be used with motors whose full-load current, locked-rotor current, or horsepower rating exceeds the values given in Tables 2-4-3 and 2-4-4. The current rating of overload relays or the trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

The full-load current, locked-rotor current or horsepower ratings of two-phase four-wire and two-phase three-wire controllers shall be the same as those shown in Table 2-4-3 for three-phase controllers. Controllers used on two-phase three-wire circuits shall be applied on the basis of the average of the currents in the three legs of the two-phase circuit.

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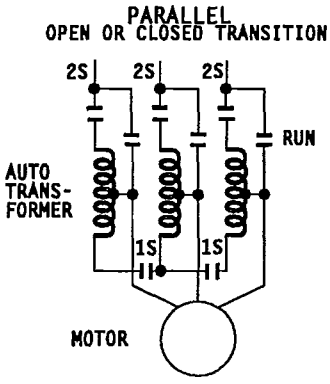
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THREE-COIL TRANSFORMER



A

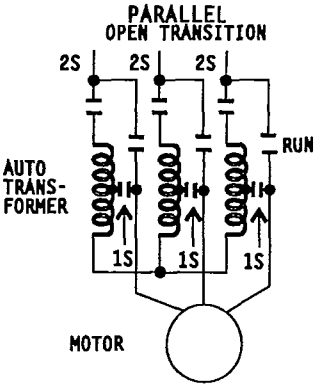
CONTACTOR SEQUENCE			
CON-TACTOR	START	TRAN-SITION	RUN
M	X	X	X
S	X		
RUN			X



B

CONTACTOR SEQUENCE					
CON-TACTOR	START	OPEN TRANSI-TION	CLOSED TRANSITION		RUN
			1	2	
1S	X				
2S	X		X	X	
RUN				X	X

FOR OPEN TRANSITION 1S AND 2S MAY BE CONTACTS OF SAME CONTACTOR

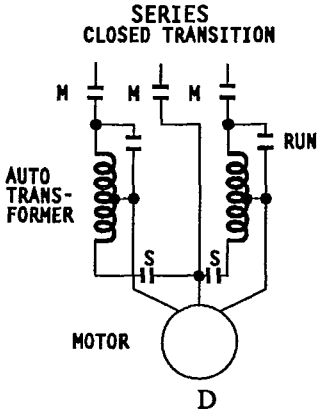


C

CONTACTOR SEQUENCE		
CONTACTOR	START	RUN
1S	X	
2S	X	
RUN		X

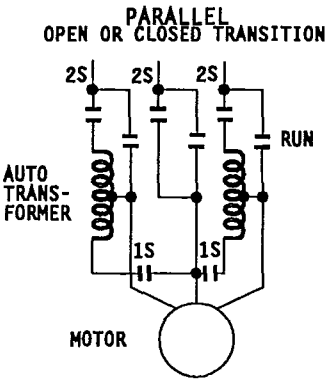
OPEN TRANSITION 1S AND 2S MAY BE CONTACTS OF SAME CONTACTOR

TWO-COIL TRANSFORMER



D

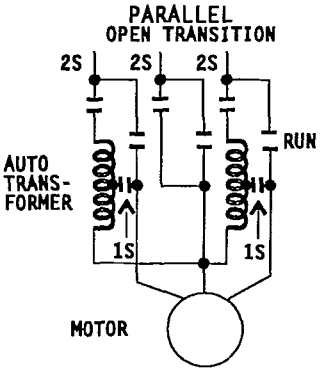
CONTACTOR SEQUENCE			
CON-TACTOR	START	TRAN-SITION	RUN
M	X	X	X
S	X		
RUN			X



E

CONTACTOR SEQUENCE					
CON-TACTOR	START	OPEN TRANSI-TION	CLOSED TRANSITION		RUN
			1	2	
1S	X				
2S	X		X	X	
RUN				X	X

FOR OPEN TRANSITION 1S AND 2S MAY BE CONTACTS OF SAME CONTACTOR



F

CONTACTOR SEQUENCE		
CONTACTOR	START	RUN
1S	X	
2S	X	
RUN		X

OPEN TRANSITION 1S AND 2S MAY BE CONTACTS OF SAME CONTACTOR

Figure 2-3-7
REDUCED VOLTAGE AUTOTRANSFORMER CONTROLLERS

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Table 2-4-1
HORSEPOWER (HP) AND LOCKED-ROTOR CURRENT (LRA) RATINGS FOR THREE-PHASE, SINGLE-SPEED FULL-VOLTAGE MAGNETIC CONTROLLERS FOR LIMITED PLUGGING AND JOGGING-DUTY

Size of Controller	Continuous Current Rating* (Amperes)	At 200V - 60HZ		At 230V - 60HZ		At 380V - 50HZ		At 380V - 50HZ		Service-limit Current Rating* (Amperes)
		HP	LRA	HP	LRA	HP	LRA	HP	LRA	
00	9	1-1/2	46	1-1/2	40	1-1/2	30	2	25	11
0	18	3	74	3	70	5	64	5	53	21
1	27	7-1/2	151	7-1/2	140	10	107	10	88	32
2	45	10	255	15	255	25	255	25	210	52
3	90	25	500	30	500	50	500	50	418	104
4	135	40	835	50	835	75	835	100	835	156
5	270	75	1670	100	1670	150	1670	200	1670	311
6	540	150	3340	200	3340	300	3340	400	3340	621
7	810	---	---	300	5000	---	---	600	5000	932
8	1215	---	---	450	7500	---	---	900	7500	1400
9	2250	---	---	800	13400	---	---	1600	13400	2590

* See 4.1.2

Table 2-4-2
HORSEPOWER (HP) AND LOCKED-ROTOR CURRENT (LRA) RATINGS FOR SINGLE-PHASE FULL-VOLTAGE MAGNETIC CONTROLLERS FOR LIMITED PLUGGING AND JOGGING DUTY 50 OR 60 HERTZ

Size of Controller	Continuous Current Rating (Amperes)	At 115V		At 230 V		Service Limit Current Rating* (Amperes)
		HP	LRA	HP	LRA	
00	9	1/3	50	1	45	11
0	18	1	80	2	65	21
1	27	2	130	3	90	32
1P	36	3	140	5	135	42
2	45	3	250	7-1/2	250	52
3	90	7-1/2	500	15	500	104

* See 4.1.2

4.1.6 Ratings of Reduced-Voltage General-Purpose Controllers

Reduced-voltage general-purpose controllers include primary resistor controllers, autotransformer controllers, and reactor controllers.

The ratings of reduced-voltage general-purpose reversing or nonreversing controllers, when mounted in any type of enclosure and whether or not provided with running overcurrent (overload) protection or other auxiliary devices, shall be in accordance with:

a. Table 2-4-5 for three-phase controllers
b. Table 2-4-6 for single-phase controllers

These controllers shall not be used with motors whose full-load current, locked-rotor current, or horsepower rating exceeds the values given in Tables 2-4-5 and 2-4-6. The current rating of overload relays or the trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

The horsepower ratings of two-phase four-wire and two-phase three-wire controllers shall be the same as those shown in Table 2-4-5 for three-phase controllers. Controllers used on two-phase three-wire circuits shall be applied on the basis of the average of the currents in the three legs of the two-phase circuit.

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Table 2-4-3
HORSEPOWER (HP) AND LOCKED-ROTOR CURRENT (LRA) RATINGS FOR THREE-PHASE, SINGLE-SPEED, FULL-VOLTAGE MAGNETIC CONTROLLERS FOR PLUG-STOP, PLUG-REVERSE OR JOGGING-DUTY

Size of Controller	Continuous Current Rating (Amperes)	At 200V - 60HZ		At 230V - 60HZ		At 380V - 50HZ		At 460V - 60HZ		At 575V - 60HZ		Service Limit Current Rating * (Amperes)
		HP	LRA	HP	LRA	HP	LRA	HP	LRA	HP	LRA	
0	18	1.5	46	1.5	40	1.5	30	2	25	2	20	21
1	27	3	74	3	70	5	63	5	52	5	42	32
2	45	7.5	175	10	175	15	154	15	127	15	102	52
3	90	15	335	20	335	30	300	30	250	30	200	104
4	135	25	500	30	500	50	500	60	500	60	400	156
5	270	60	1250	75	1250	125	1250	150	1250	150	1000	311
6	540	125	2500	150	2500	250	2500	300	2500	300	2000	621

* See Part 4.1.2

Table 2-4-4
HORSEPOWER (HP) AND LOCKED-ROTOR CURRENT (LRA) RATINGS FOR SINGLE-PHASE FULL-VOLTAGE MAGNETIC CONTROLLERS FOR PLUG-STOP, PLUG-REVERSE, OR JOGGING DUTY 50 OR 60 HERTZ

Size of Controller	Continuous Current Rating (Amperes)	At 115V		At 230V		Service Limit Current Rating * (Amperes)
		HP	LRA	HP	LRA	
0	18	0.5	53	1	43	21
1	27	1	87	2	60	32
1P	36	1.5	93	3	90	42
2	45	2	150	5	150	52
3	90	5	300	10	300	104

* See Part 4.1.2

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TABLE 2-4-5
HORSEPOWER (HP) AND LOCKED-ROTOR CURRENT (LRA) RATINGS FOR THREE-PHASE, REDUCED-VOLTAGE MAGNETIC CONTROLLERS FOR LIMITED PLUGGING AND JOGGING-DUTY

Size of Controller	Continuous Current Rating (Amperes)	At 200V - 60HZ		At 230V - 60HZ		At 380V - 50HZ		At 460V - 60HZ		At 575V - 60HZ		Service Limit Current Rating * (Amperes)
		HP	LRA	HP	LRA	HP	LRA	HP	LRA	HP	LRA	
1	27	7.5	152	7.5	140	10	107	10	88	10	70	32
2	45	10	255	15	255	25	255	25	210	25	163	52
3	90	25	500	30	500	50	500	50	418	50	334	104
4	135	40	835	50	835	75	835	100	835	100	668	156
5	270	75	1670	100	1670	150	1670	200	1670	200	1334	311
6	540	150	3340	200	3340	300	3340	400	3340	400	2670	621
7	810	---	---	300	5000	---	---	600	5000	600	4000	932
8	1215	---	---	450	7500	---	---	900	7500	900	6000	1400
9	2250	---	---	800	13400	---	---	1600	13400	1600	10700	2590

* See Part 4.1.2

TABLE 2-4-6
HORSEPOWER (HP) AND LOCKED-ROTOR CURRENT (LRA) RATINGS FOR SINGLE-PHASE REDUCED-VOLTAGE MAGNETIC CONTROLLERS FOR LIMITED PLUGGING AND JOGGING-DUTY 50 OR 60 HERTZ

Size of Controller	Continuous Current Rating (Amperes)	At 115V		At 230V		Service Limit Current Rating* (Amperes)
		HP	LRA	HP	LRA	
1	27	2	130	3	90	32
1P	36	3	140	5	135	42
2	45	3	250	7.5	250	52
3	90	7.5	500	15	500	104

* See Part 4.1.2

The accelerating contactor of single-step two-point controllers shall be of the same size as the line contactor when the line contactor is Size 4 or smaller. When the line contactor is Size 5 or larger, an accelerating contactor of the next smaller size shall be permitted to be used.

Accelerating contactors for multistep controllers and for increment (network) controllers shall be selected so that the rating for each resistor step will be not less than one-sixth times the maximum rms current for that step.

Resistors for controllers with automatic acceleration shall be Class Number 116 except where the application requires the use of other duty resistors. See ICS 9, Part 2.

For refrigeration and air-conditioning applications, the controller shall be suitable for a duty cycle of:

a. For Primary Resistor- and Reactor-type Controllers—One start per hour not to exceed 30 seconds.
b. For Autotransformer-type Controllers:

Tap, Percent	Start After 5 Hours or Longer Shutdown, Not to Exceed	One Start per Hour, Not to Exceed
50 to 65	90 seconds	60 seconds
80	45 seconds	30 seconds

4.1.7 Ratings of Wye-Delta Magnetic Controllers

The full-load current, locked-rotor current, or horsepower ratings of wye-delta magnetic controllers shall be in accordance with Table 2-4-7.

4.1.8 Ratings of Part-Winding Controllers

The horsepower ratings for full-voltage, part-winding controllers shall be in accordance with Table 2-4-8.

The current ratings for full-voltage, part-winding controllers shall be in accordance with Table 2-4-9.

The horsepower ratings for reduced-voltage, part-winding controllers shall be in accordance with Table 2-4-10.

The current ratings for reduced-voltage, part-winding controllers shall be in accordance with Table 2-4-11.

4.1.9 Ratings of Three-Phase Multispeed Controllers for Limited Plugging and Jogging Duty

4.1.9.1 For Constant-Torque and Variable-Torque Motors (Two, Three and Four Speeds)

For limited plugging and jogging duty the ratings of these controllers shall be in accordance with Table 2-4-12. These controllers shall not be used with motors whose full-load current or horsepower ratings exceed the continuous current or horsepower ratings given in Table 2-4-12. The current rating of overcurrent overload relays or the trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

4.1.9.2 For Constant-Horsepower Motors (Two, Three and Four Speeds)

The ratings of these controllers for limited plugging and jogging, reversing and nonreversing duty, requiring five or less openings per minute, when mounted in any type of enclosure and whether or not provided with running overcurrent (overload) protection or other auxiliary devices, shall be in accordance with Table 2-4-13.

4.1.10 Ratings of Three-Phase Controllers for Plug-Stop, Plug-Reverse or Jogging Duty

The ratings of controllers for constant-torque, variable-torque and constant-horsepower motors for plug-stop, plug-reverse or jogging duty shall be in accordance with 4.1.5 and Table 2-4-3.

4.1.11 Ratings of Primary Contactors of Magnetic Wound-Rotor Motor Controllers for Reversing and Nonreversing Duty

The ratings of primary contactors of wound-rotor motor controllers for reversing and nonreversing duty, when mounted in any type of enclosure and whether or not provided with running overcurrent (overload) protection or other auxiliary devices, shall be as shown in Table 2-4-14.

These controllers shall not be used with motors whose full-load current or horsepower rating exceeds the continuous current or horsepower rating given in Table 2-4-14. The current rating of overload relays or the trip current of other motor protective devices used shall not exceed the service-limit current rating of the controller.

The horsepower ratings of two-phase four-wire and two-phase three-wire controllers shall be the same as those shown in Table 2-4-14.

Controllers used on two-phase three-wire circuits shall be applied on the basis of the average of the currents in the three legs of the two-phase circuit.

4.1.12 Service Classification of Resistors for Wound-Rotor Motor Secondary Circuits

Resistors for controllers with automatic acceleration shall be Class No. 135 or 136 except where the application requires the use of other duty resistors. See ICS 9, Part 2.

4.1.13 Accelerating (Secondary) Contactors of Magnetic Wound-Rotor Motor Controllers for Reversing and Nonreversing Duty

For nonplugging reversing and nonreversing service, wound-rotor motor controllers shall be provided with the

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TABLE 2-4-7
HORSEPOWER (HP) AND LOCKED-ROTOR CURRENT (LRA) RATINGS FOR WYE-DELTA MAGNETIC CONTROLLERS FOR EITHER OPEN OR CLOSED TRANSITION

Size of Controller	Continuous Current Rating (Amperes)	Contactor Size			At 200V - 60HZ		At 230V - 60HZ		At 380V - 50HZ		At 460V - 60HZ		At 575V - 60HZ		Service-limit Current Rating* (Amperes)
		1M & 2M†	S & 1S	2S	HP	LRA	HP	LRA	HP	LRA	HP	LRA	HP	LRA	
1YD	47	1	1	‡	10	263	10	242	15	185	15	152	15	121	55
2YD	78	2	2	‡	20	441	25	441	40	441	40	363	40	291	90
3YD	156	3	3	‡	40	866	50	866	75	866	75	725	75	578	179
4YD	233	4	4	‡	60	1445	75	1445	150	1445	150	1445	150	1155	270
5YD	467	5	4	‡	150	2510	150	2510	250	2510	300	2510	300	2000	538
6YD	935	6	5	‡	300	5020	350	5020	500	5020	700	5020	700	4000	1075
7YD	1400	7	6	‡	500	8660	500	8660	800	8660	1000	8660	1000	6930	1610
8YD	2100	8	7	‡	750	13000	800	13000	1000	13000	1500	13000	1500	10400	2420
9YD	3900	9	8	‡	1500	23200	1500	23200	2000	23200	3000	23200	3000	18500	4480

*See Part 4.1.2.
†Each contactor 1M and 2M carries only 0.577 times the motor line current when the motor is switched to the delta (running) connections. See Part 3.5.2 and Figure 3-6.
‡Contactor 2S shall be capable of interrupting the current in the transition resistor circuit.

TABLE 2-4-8
HORSEPOWER (HP) RATINGS FOR THREE-PHASE FULL VOLTAGE PART-WINDING CONTROLLERS FOR LIMITED PLUGGING AND JOGGING-DUTY 50 OR 60 HERTZ

Size of Controller	Continuous Current Rating (Amperes)	Contactor Size † (1M & 2M)	Three-Phase Horsepower at **				Service Limit Current Rating * (Amperes)
			60 Hertz 200V	60 Hertz 230V	50 Hertz 380V	60 Hertz 460 or 575V	
1PW	54	1	10	10	15	15	64
2PW	90	2	20	25	40	40	104
3PW	180	3	40	50	75	75	208
4PW	270	4	75	75	150	150	312
5PW	540	5	150	150	250	350	622
6PW	1080	6	---	300	500	600	1242
7PW	1620	7	---	450	800	900	1864
8PW	2430	8	---	700	---	1400	2800
9PW	4500	9	---	1300	---	2600	5180

*See Part 4.1.2
†Contactors 1M and 2M are each intended to carry one-half of the motor running line current. See Clause 2-3.3 and Figure 2-3-2.
**The horsepower ratings are based on locked-rotor currents corresponding to 65 percent of the full-winding values.

Table 2-4-9
RATINGS FOR NONPLUGGING NONJOGGING FULL-VOLTAGE POLYPHASE MAGNETIC CONTROLLERS FOR MOTORS SUITABLE FOR PART-WINDING STARTING

Size of Controller	Continuous Current Rating per Winding,* Amperes	Contactor Size Line† (1 M and 2 M)	Locked-Rotor Rating per Winding Amperes at					Service-Limit Current* Rating per Winding,* Amperes
			60 Hertz		50 Hertz	60 Hertz		
			200 Volts	230 Volts	380 Volts	460 Volts		
1PW	27	1	152	140	107	88	70	32
2PW	45	2	255	255	255	210	168	52
3PW	90	3	500	500	500	418	334	104
4PW	135	4	835	835	835	835	668	156
5PW	270	5	1670	1670	1670	1670	1334	311
6PW	540	6	...	3340	3340	3340	2670	621
7PW	810	7	...	5000	5000	5000	4000	932
8PW	1215	8	...	7500	...	7500	6000	1400
9PW	2250	9	...	13400	...	13400	10700	2590

* See 4.1.2.

† Contactors 1M and 2M are each intended to carry one half of the motor running line current. See 3.3 and Figure 2-3-2.

NOTE—These ratings are established on a per-winding basis because, on part-winding starting, the locked-rotor current is considerably in excess of 50 percent of the total locked-rotor rating of the motor. The percentage varies over a wide range, depending on motor design.

Table 2-4-10
RATINGS FOR REDUCED-VOLTAGE PART-WINDING CONTROLLERS FOR NONPLUGGING, NONJOGGING DUTY

Size of Controller	Continuous Current Rating, * Amperes	Contractor Size		Three-Phase Horsepower at**				Service-Limit Current Rating* Amperes
		Line† (1 M and 2 M)	Accelerating	60 Hertz		50 Hertz	60 Hertz	
				200 Volts	230 Volts	380 Volts	460 or 575 Volts	
1PW	54	1	1	10	10	15	15	64
2PW	90	2	2	20	25	40	40	104
3PW	180	3	3	40	50	75	75	208
4PW	270	4	4	75	75	150	150	312
5PW	540	5	4††	150	150	250	350	622
6PW	1080	6	5††	...	300	500	600	1242
7PW	1620	7	6††	...	450	800	900	1864
8PW	2430	8	7††	...	700	...	1400	2800
9PW	4500	9	8††	...	1300	...	2600	5180

* See 4.1.2.

† Contactors 1M and 2M are each intended to carry one half of the motor running line current. See 3.3 and Figure 2-3-2.

†† The use of one size smaller accelerating contactor on sizes 5PW and larger is suitable when the contactor is shunted by its associated line contactor.

** The horsepower ratings are based on locked-rotor currents corresponding to 65 percent of the full-winding values.

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Table 2-4-11
RATINGS FOR NONPLUGGING NONJOGGING REDUCED-VOLTAGE POLYPHASE MAGNETIC CONTROLLERS FOR MOTORS SUITABLE FOR PART-WINDING STARTING

Size of Controller	Continuous Current Rating per Winding,* Amperes	Contractor Size		Locked-Rotor Rating per Winding Amperes at					Service Limit Current Rating per Winding,* Amperes
				60 Hertz		50 Hertz	60 Hertz		
		Line† (1 M and 2 M)	Accelerating	200 Volts	230 Volts	380 Volts	460 Volts	575 Volts	
1PW	27	1	1	152	140	107	88	70	32
2PW	45	2	2	255	255	255	210	168	52
3PW	90	3	3	500	500	500	418	334	104
4PW	135	4	4	835	835	835	835	668	156
5PW	270	5	4††	1670	1670	1670	1670	1334	311
6PW	540	6	5††	...	3340	3340	3340	2670	621
7PW	810	7	6††	...	5000	5000	5000	4000	932
8PW	1215	8	7††	...	7500	...	7500	6000	1400
9PW	2250	9	8††	...	13400	...	13400	10700	2590

* See 4.1.2.

† Contactors 1M and 2M are each intended to carry one half of the motor running line current. See 3.3 and Figure 2-3-2.

†† The use of one size smaller accelerating contactor on sizes 5PW and larger is suitable when the contactor is shunted by its associated line contactor.

NOTE—These ratings are established on a per-winding basis because, on part-winding starting, the locked-rotor current is considerably in excess of 50 percent of the total locked-rotor current rating of the motor. The percentage varies over a wide range, depending on motor design.

Table 2-4-12
HORSEPOWER RATINGS FOR THREE-PHASE MULTISPEED MAGNETIC CONTROLLERS FOR LIMITED PLUGGING AND JOGGING-DUTY FOR CONSTANT-TORQUE AND VARIABLE-TORQUE MOTORS (TWO, THREE AND FOUR SPEED) 50 OR 60 HERTZ

Size of Controller	Continuous Current Rating (Amperes)	Horsepower† at				Service Limit Current Rating * (Amperes)
		60 Hertz 200V	60 Hertz 230V	50 Hertz 380V	60 Hertz 460 or 575V	
0	18	3	3	5	5	21
1	27	7.5	7.5	10	10	32
2	45	10	15	25	25	52
3	90	25	30	50	50	104
4	135	40	50	75	100	156
5	270	75	100	150	200	311
6	540	150	200	300	400	621
7	810	...	300	...	600	932
8	1215	...	450	...	900	1400
9	2250	...	800	...	1600	2590

* See 4.1.2.

† These horsepower ratings are based on the locked-rotor current ratings given in Table 2-4-1. For motors having higher locked-rotor currents, a larger controller should be used so that its locked-rotor current rating is not exceeded.

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Table 2-4-13
HORSEPOWER RATINGS FOR THREE-PHASE MULTISPEED MAGNETIC CONTROLLERS FOR LIMITED PLUGGING AND JOGGING-DUTY FOR CONSTANT-HORSEPOWER MOTORS (TWO, THREE AND FOUR SPEED) 50 OR 60 HERTZ

Size of Controller	Continuous Current Rating (Amperes)	Horsepower† at 60 Hertz 200V	60 Hertz 230V	50 Hertz 380V	60 Hertz 460V or 575V	Service Current Rating* (Amperes)
0	18	2	2	3	3	21
1	27	5	5	7.5	7.5	32
2	45	7.5	10	20	20	52
3	90	20	25	40	40	104
4	135	30	40	60	75	156
5	270	60	75	100	150	311
6	540	100	150	200	300	621
7	810	---	225	---	450	932
8	1215	---	350	---	700	1400
9	2250	---	600	---	1200	2590

* See 4.1.2.
† These horsepower ratings are based on the locked-rotor current ratings given in Table 2-4-1. For motors having higher locked-rotor currents, a larger controller should be used so that its locked-rotor current rating is not exceeded.

Table 2-4-14
HORSEPOWER RATIMGS FOR THREE-PHASE PRIMARY CONTACTORS OF MAGNETIC WOUND-ROTOR MOTOR CONTROLLERS FOR REVERSING AND NONREVERSING DUTY 50 OR 60 HERTZ

Size of Controller	Continuous Current Rating (Amperes)	Three-Phase Horsepower 115V	230V	460 or 575V	Service Limit Current Rating * (Amperes)
1	27	3	7.5	10	32
2	45	---	15	25	52
3	90	---	30	50	104
4	135	---	50	100	156
5	270	---	100	200	311
6	540	---	200	400	621
7	810	---	300	600	932
8	1215	---	450	900	1400
9	2250	---	800	1600	2590

* See 4.1.2.

minimum number of accelerating contactors shown in Table 2-4-15.

Where a controller is used for reversing plugging service, one plugging contactor shall be added to the number of contactors required for acceleration.

The intermediate accelerating contactors and plugging contactors, where required for automatically accelerating contactors, shall be so selected that the rating will be not less than one-sixth times the maximum rms accelerating current for that step.

The final accelerating contactor shall be so selected that the continuous rating will be not less than the motor rated secondary current.

Where a three-pole accelerating contactor is connected in closed delta, its current rating shall be 150 percent of the current rating of the corresponding two-pole contactor connected in open delta.

4.2 Short-Circuit Current Ratings

Class A controllers (with a specified short circuit protective device) shall have one or more short-circuit current ratings expressed in maximum available fault current (rms symmetrical amperes) at the rated system voltage. The power factor (X/R ratio) shall be as given in UL 508. Standard short-circuit current ratings are shown in Table 2-4-16.

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Table 2-4-15
ACCELERATING CONTACTORS FOR WOUND ROTOR MOTOR CONTROLLERS

Horsepower Rating	Minimum Number of Accelerating Contactors
15	1
75	2
150	3
300	4
600	5
1200	6

Table 2-4-16
SHORT CIRCUIT CURRENT RATINGS (RMS SYMMETRICAL AMPERES)

1,000	22,000	65,000
5,000	25,000	85,000
7,500	30,000	100,000
10,000	35,000	125,000
14,000	42,000	150,000
18,000	50,000	200,000

4.3 Nonmotor Load Applications—Ratings of the Contactor Portion of the Controllers

4.3.1 For Applications Other Than Capacitor Switching

For nonmotor loads other than capacitors the ratings shall be in accordance with Table 2-4-17.

These ratings are based on the use of two poles to control the load for single phase (Figure 2-4-1) or three poles to control the load for three phase (Figure 2-4-2) up to 600 volts maximum.

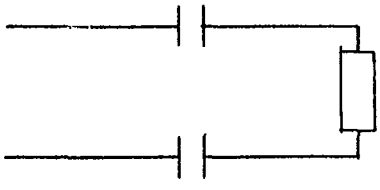


Figure 2-4-1
SINGLE-PHASE LOAD

One pole may be used for single-pole control of a single-phase load where one line is grounded (Figure 2-4-3), and the maximum voltage rating is 300 volts.

4.3.2 For Capacitor Switching

Contactors are used to switch capacitors under three general conditions:

a. In association with a motor for individual motor power factor correction
b. To switch a single capacitor or single capacitor bank into and out of an electrical distribution system
c. To switch a single capacitor or single capacitor bank into and out of an electrical distribution system which has other capacitor banks already operating in the system

The kilovar ratings of enclosed, three-phase, AC, low-voltage contactors employed as magnetic switches for power capacitor loads, where only one such load appears on the secondary of a distribution system, shall be as shown in Tables 2-4-18 through 2-4-20. See 9.3 for application information.

Where more than one capacitor load appears on the secondary of a distribution system, contactors may be applied in accordance with Tables 2-4-18 through 2-4-20 provided the capacitor surge current does not exceed the maximum shown in Table 2-4-17 for the contactor size.

Contactors used in capacitor circuits where there is a high available fault current should be protected by suitable short-circuit protective means.

5 Product Marking, Installation and Maintenance Information

5.1 General Maintenance

A maintenance program and schedule should be established to meet the needs of each particular installation to assure minimum down time. The program should include, for example, tightening connections, inspecting for evidence of overheating, removing dust and dirt, and replacing contacts when worn or when the contact follow-up and pressure have been reduced to a level which might impair the operation of the equipment.

See ICS 1.3 for preventive maintenance instructions.

5.2 Maintenance After a Fault

Annex A of this publication covers the procedures to be followed in order to return to service a motor controller which has been subjected to a short circuit or a ground fault.

6 Service and Storage Conditions

See ICS 1, Clause 6.

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Table 2-4-17
GENERAL-PURPOSE CONTACTOR RATINGS

Size of Contactor	Continuous Carrying Current, RMS Amperes		Direct Load Switching RMS Ampere Rating				Transformer Primary Switching kVA Open or Enclosed													
			Maximum Circuit-Closing (Amps Peak Including Offset)	Tungsten Lamp Loads, 300 Volts Maximum†	Resistive Loads and Electric Discharge Lamp Loads**		Transformers Having Inrush Current (Worst Case Peak) of Not More than 20 Times Peak of Continuous-Current Rating								Transformers Having Inrush Currents (Worst Case Peak) of Over 20 Through 40 Times Peak of Continuous-Current Rating							
							Single Phase Volts				Three Phase Volts				Single Phase Volts				Three Phase Volts			
	Enclosed	Open	Open or Enclosed	Open or Enclosed	Enclosed	Open	120	240	480	600	208	240	480	600	120	240	480	600	208	240	480	600
00	9	10	87	5	9	10																
0	18	20	140	10	18	20	0.6	1.2	2.4	3.0	1.8	2.1	4.2	5.2	0.3	0.6	1.2	1.5	0.9	1.0	2.1	2.6
1	27	30	288	15	27	30	1.2	2.4	4.9	6.2	3.6	4.3	8.5	11.0	0.6	1.2	2.5	3.1	1.8	2.1	4.3	5.3
2	45	50	483	30	45	50	2.1	4.1	8.3	10.0	6.3	7.2	14.0	18.0	1.0	2.1	4.2	5.2	3.1	3.6	7.2	8.9
3	90	100	947	60	90	100	4.1	8.1	16.0	20.0	12.0	14.0	28.0	35.0	2.0	4.1	8.1	10.0	6.1	7.0	14.0	18.0
4	135	150	1581	120	135	150	6.8	14.0	27.0	34.0	20.0	23.0	47.0	59.0	3.4	6.8	14.0	17.0	10.0	12.0	23.0	29.0
5	270	300	3163	240	270	300	14.0	27.0	54.0	68.0	41.0	47.0	94.0	117.0	6.8	14.0	27.0	34.0	20.0	24.0	47.0	59.0
6	540	600	6326	480	540	600	27.0	54.0	108.0	135.0	81.0	94.0	188.0	234.0	14.0	27.0	54.0	68.0	41.0	47.0	94.0	117.0
7	810	900	9470		810	900																
8	1215	1350	14205		1215	1350																
9	2250	2500	25380		2250	2500																

* Enclosed ratings apply in any type of enclosure.

† Tungsten lamp loads include infra-red lamps having tungsten filaments.

** Electric discharge lamps are those such as fluorescent, mercury vapor, etc.

Table 2-4-18
CONTACTOR RATINGS FOR SINGLE CAPACITOR OR CAPACITOR BANK SWITCHING AT 230 VOLTS 60 HZ

Size of Controller	Continuous Ratings RMS Amperes	Three-Phase Rating of Capacitor					
		Maximum Size of Three-Phase Capacitor in kVar for Available Current* in Amperes RMS Sym.					
		3000	5000	10,000	14,000	18,000	22,000
2	45	12	8	4	3	2	2
3	90	27	27	15	11	9	7
4	135	40	40	40	30	24	20
5	270	80	80	80	80	80	75
6	540	160	160	160	160	160	160
7	810	240	240	240	240	240	240
8	1215	360	360	360	360	360	360
9	2250	665	665	665	665	665	665

* Available at capacitor terminals.

Table 2-4-19
CONTACTOR RATINGS FOR SINGLE CAPACITOR OR CAPACITOR BANK SWITCHING AT 460 VOLTS 60 HZ

Size of Controller	Continuous Ratings RMS Amperes	Three-Phase Rating of Capacitor					
		Maximum Size of Three-Phase Capacitor in kVar for Available Current* in Amperes RMS Sym.					
		3000	5000	10,000	14,000	18,000	22,000
2	45	25	16	8	6	4	4
3	90	53	53	31	23	18	15
4	135	80	80	80	61	49	41
5	270	160	160	160	160	160	149
6	540	320	320	320	320	320	320
7	810	480	480	480	480	480	480
8	1215	720	720	720	720	720	720
9	2250	1325	1325	1325	1325	1325	1325

* Available at capacitor terminals.

Table 2-4-20
CONTACTOR RATINGS FOR SINGLE CAPACITOR OR CAPACITOR BANK SWITCHING AT 575 VOLTS 60 HZ

Size of Controller	Continuous Ratings RMS Amperes	Three-Phase Rating of Capacitor					
		Maximum Size of Three-Phase Capacitor in kVar for Available Current* in Amperes RMS Sym.					
		3000	5000	10,000	14,000	18,000	22,000
2	45	31	20	10	7	6	5
3	90	67	67	39	29	23	19
4	135	100	100	100	77	61	51
5	270	200	200	200	200	200	189
6	540	400	400	400	400	400	400
7	810	600	600	600	600	600	600
8	1215	900	900	900	900	900	900
9	2250	1670	1670	1670	1670	1670	1670

* Available at capacitor terminals.

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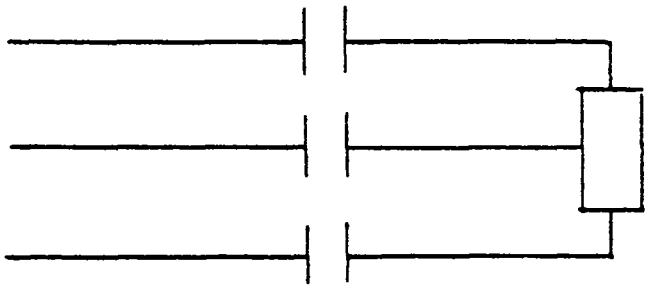


Figure 2-4-2
THREE-PHASE LOAD

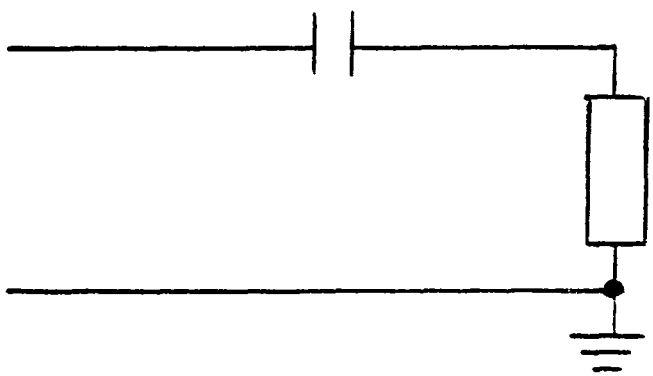


Figure 2-4-3
SINGLE-PHASE LOAD—ONE LINE GROUNDED

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7 Construction

7.1 Control Transformer Overcurrent Protection

Where a stepdown transformer is provided in an AC controller to supply power to the control circuit, it shall be protected in accordance with the National Electrical Code, Section 430-72, or other applicable codes. Where overcurrent protection is provided in the secondary, it shall be located as shown in Figure 2-7-1.

7.2 Terminals and Connections

7.2.1 Terminal Markings for Full-Voltage Single-Speed Magnetic Controllers

All controllers shall be marked and wired in accordance with Table 2-7-1, where applicable.

The sequence of line and load terminal markings shall be L1, L2, L3, L4 and T1, T2, T3, T4, reading from left to right when looking at the front of the controller. If the leads come in to the left or right of the controller, then the sequence of lead numbering shall be the same as if the controller were rotated to these positions.

Where a STOP button is assembled with the controller, it may actuate the contacts of the overload relays.

Where a three-phase three-pole nonreversing full-voltage controller is used on a two-phase three-wire or two-phase four-wire application, Figure 2-7-2 or a suitable note, or a combination of both, should be used as a guide in making connections.

Control circuit contacts, such as those of pushbuttons, master switches, relays and interlocks, should be connected between L1 and associated coils. Exceptions include circuits controlled by double-pole contacts opening both sides of a circuit, motor running overcurrent device contacts, and electrical interlocks whose circuit wiring between coils and L2 does not extend beyond the controller enclosure.

Where terminals are provided for external START-STOP pushbutton switches for nonreversing controllers, the controller terminals shall be marked 1, 2 and 3 as indicated in Figure 2-7-3.

Control circuit markings for reversing controllers shall be 1, 2, 3, 4, 5, 6 and 7 and in accordance with Figure 2-7-4.

7.2.2 Terminal Markings for Part-Winding Magnetic Controllers

7.2.2.1 Controllers with Three-Pole Contactors

For controllers having three-pole contactors, the controller terminal markings shall be as follows:

a. For the section of the motor winding first connected to the supply lines: T1, T2, T3
b. For the other section of the motor winding: T7, T8, T9

7.2.2.2 Controllers with a Four-Pole and Two-Pole Contactor

For controllers having a four-pole contactor and a two-pole contactor, the controller terminal markings shall be as follows:

a. For the section of the motor winding first connected to the supply lines: A, B, C, D
b. For the other section of the motor winding: E, F

7.2.3 Control Circuit Terminal Markings for Two-Speed Magnetic Controllers

Magnetic controllers for two-speed motors shall have control circuit terminals marked in accordance with Figure 2-7-5.

7.3 Location of Overload Relay Contacts in Circuit

The contacts of overload relays are located as shown in Figures 2-7-3 and 2-7-4 so as to minimize the exposure of these contacts to fault currents which might weld them closed. Since these contacts are normally closed, a welded condition may remain undetected and result in the loss of running overcurrent protection. In the case of reversing and some other multiple contactor controllers, a single overload relay should be used to sense the state of the motor, regardless of the direction of rotation or the duty cycle.

Analysis of Figure 2-7-4 reveals that the overload relay contacts can perform their function for both directions of rotation only if they are located as shown or connected on either side of the STOP button. However, if the overload relay contacts are located on either side of the STOP button, they may be exposed to a ground fault current in the remote control station wiring.

The foregoing applies to the control circuit shown in Figure 2-7-3 except that another location, to the left of the coil, is available. In this location, the risk of welding contacts is present when L2 is grounded, as it often is, and a short circuit occurs between the coil winding and grounded parts of the controller, which may be the case when a coil burns out.

8 Performance Requirements and Tests

8.1 General

Class A controllers shall meet the applicable test and performance requirements of Part 1 clause 8.

8.2 Performance Tests

Motor controllers shall be in accordance with Underwriters Laboratories Inc. Publication No. UL 508. (16th Edition)

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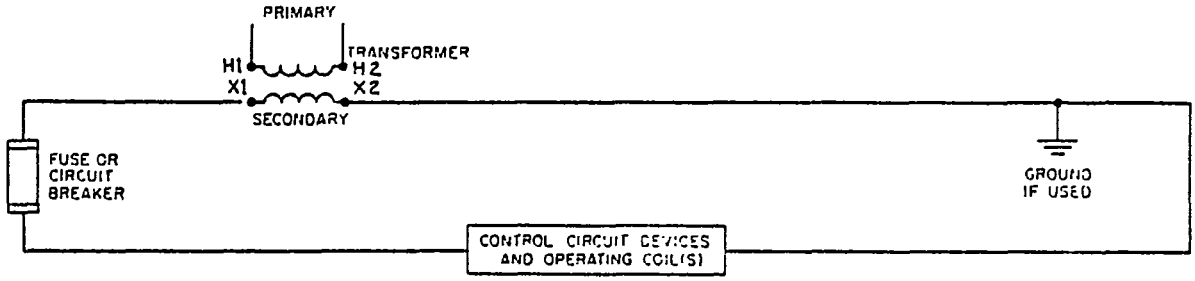
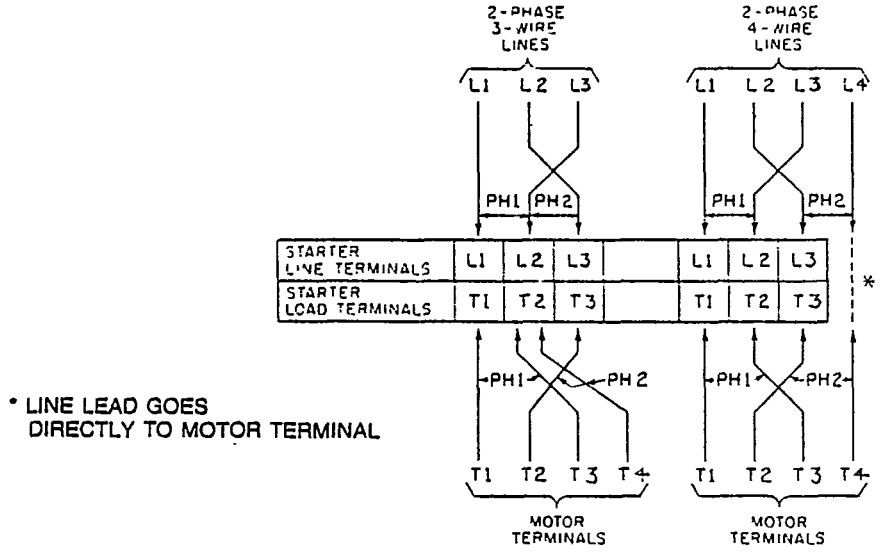


Figure 2-7-1
CONTROL CIRCUIT OVERCURRENT PROTECTION



* LINE LEAD GOES DIRECTLY TO MOTOR TERMINAL

Figure 2-7-2
THREE-PHASE CONTROLLERS FOR TWO-PHASE APPLICATIONS

Table 2-7-1
CONTROL AND POWER CONNECTIONS

	One Phase	Two Phase Four Wire	Three Phase
Line terminal markings on controller	L1, L2	L1, L3 Phase 1: L2, L4 Phase 2	L1, L2, L3
Ground when used	L1 is always	...	L2
For reversing, interchange lines	...	L1, L3	L1, L3
Motor running overcurrent units in			
1 element devices	L1	...	...
2 element devices	...	...*	...
3 element devices	...	...	L1, L2, L3
Control circuit	L1, L2	L1, L3	L1, L2

* For three pole contactors used, refer to Figure 2-7-1.

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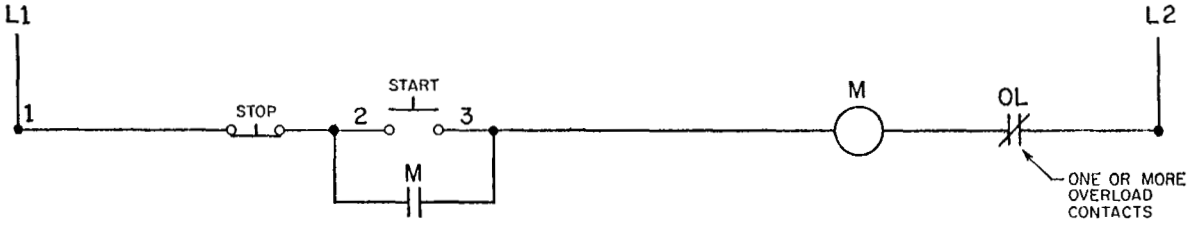
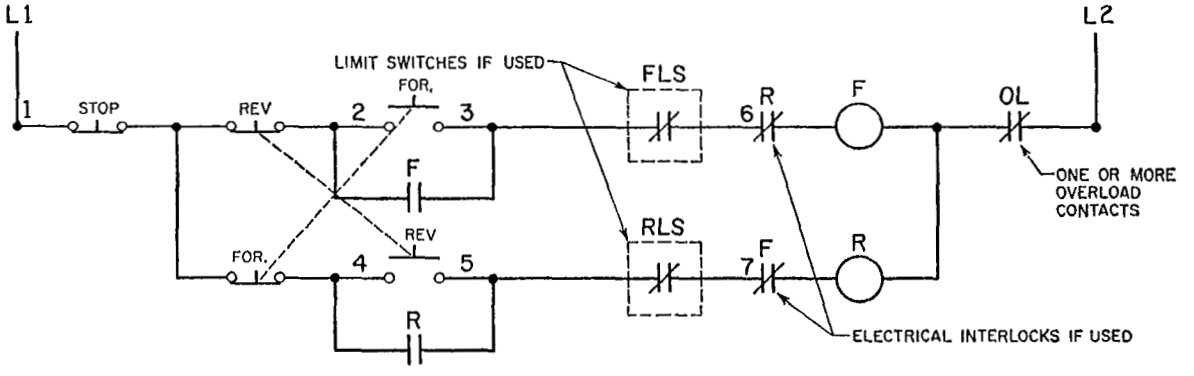


Figure 2-7-3
CONTROL CIRCUIT TERMINAL MARKINGS FOR NONREVERSING CONTROLLERS



If normally closed pushbutton contacts are omitted and wires 2 and 4 are common, the common connection shall be marked 2. If the controller is not intended for limit-switch connection, numbers 6 and 7 may be omitted.

Figure 2-7-4
CONTROL CIRCUIT TERMINAL MARKINGS FOR REVERSING CONTROLLERS

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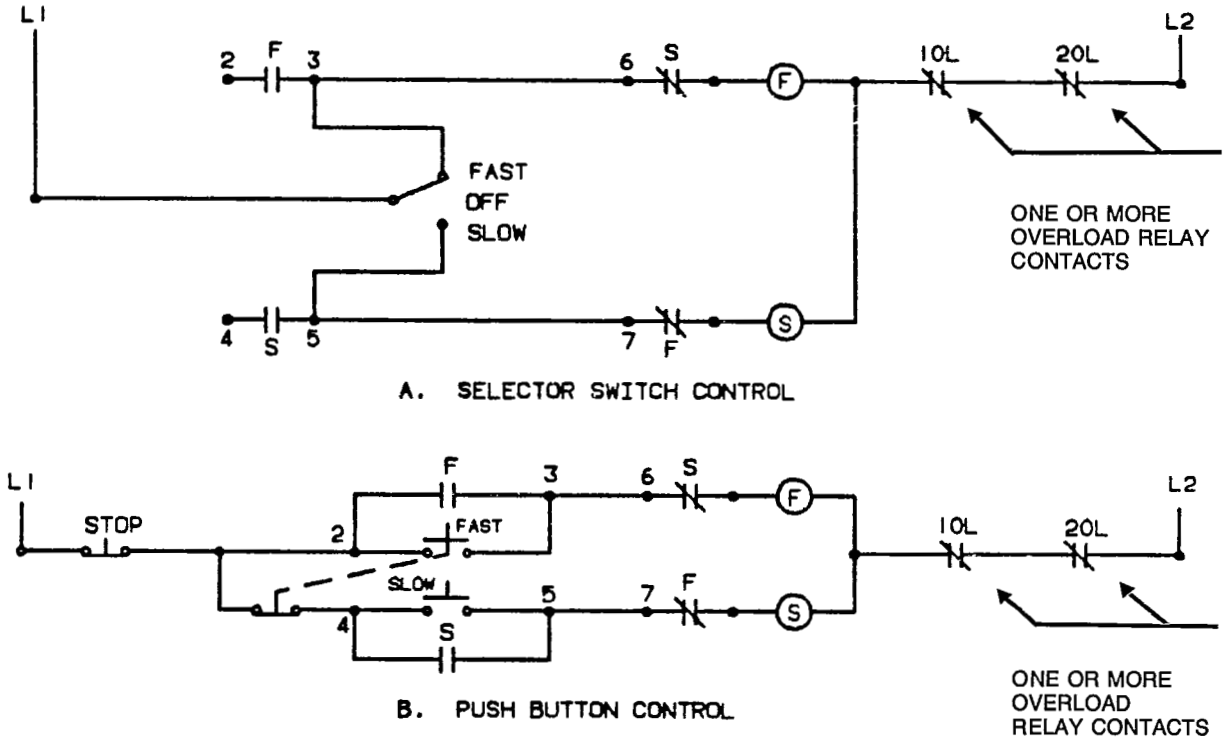


Figure 2-7-5
CONTROL CIRCUIT TERMINAL MARKINGS FOR TWO-SPEED CONTROLLERS

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8.3 Short-Time Operating Capability

8.3.1 With Overload Relay

A new Class A controller with overload relay(s) shall be capable of meeting the requirements of Clause 8 of ICS 1 at 6.4 times the current rating of its highest rated overload relay for the time necessary for its overload relay to trip.

The factor 6.4 times current rating corresponds to eight times motor full load current for a service factor 1.15 motor protected at 125 percent.

8.3.2 Without Overload Relay

A new Class A Controller without overload relays shall be capable of meeting the requirements of Clause 8 of ICS 1 at 8 times the current corresponding to the horsepower rating of the contactor for 20 seconds.

8.4 Short-Time Surge Capability

8.4.1 With Overload Relay

A new Class A controller with overload relay(s) shall be capable of meeting the requirements of Clause 8 of ICS 1 at 12 times the current rating of its highest rated overload relay for 1 second or for the time necessary for its overload relay to trip, whichever is shorter.

The factor 12 times current rating corresponds to 15 times motor full-load current for a service factor 1.15 motor, protected at 125 percent.

For convenience of testing, the duration of the surge capability test shall be permitted to be shortened (to not less than 0.9 seconds) in order to suit the available test current provided that the value of the I^2t (Joule Integral) is maintained.

8.4.2 Without Overload Relay

A new Class A controller without overload relays shall be capable of meeting the requirements of Clause 8 of ICS 1 at 15 times rated continuous current for 1 second.

For convenience of testing, the duration of the surge capability shall be permitted to be shortened (to not less than 0.9 seconds) in order to suit the available value of the test current provided that the value of the I^2t (Joule Integral) is maintained.

8.5 Design Test for Short-Circuit Current Ratings for Noncombination Controllers

Selected noncombination motor controllers and combination motor controllers which do not include short-circuit protection shall be tested to verify their ability to withstand short circuits. The short-circuit protective devices shall be selected in accordance with the National Electrical Code or the limitations marked on the controller by the manufacturer. Noncombination motor controllers shall be evaluated and marked in accordance with UL 508.

A manufacturer may determine that his designs meet the standard performance criteria by test or by a combination of test and calculation or interpolation.

9 Application

9.1 Selection of Pushbuttons for Use with Magnetic Controllers

See ICS 5, Part 5.

9.2 Nonmotor Load Applications

The following load characteristics should be considered when selecting contactors for nonmotor loads:

a. Maximum circuit-closing inrush current and duration
b. Maximum circuit-interrupting current, voltage, power factor and wave form
c. Frequency of operation and ON time
d. Rms current based on averaging time of duty cycle if other than continuous duty

Because of the endless variety of application conditions in terms of electrical loads, duty cycles, voltage fluctuations, mechanical vibration, environmental conditions, etc., contact life is not specified in these NEMA Standards. Manufacturers' recommendations should be obtained regarding specific applications.

9.3 Capacitor Applications

9.3.1 Motors with Power Factor Correction Capacitors

Capacitors used for power factor correction should be selected using the capacitor manufacturer's application data. The rating of such capacitors shall not exceed the value required to raise the no-load power factor of the motor to unity. Capacitors of these maximum ratings usually result in a full-load power factor of 0.95 to 0.98. Methods of connecting power factor correction capacitors are shown in Figure 2-9-1.

Where the capacitor is connected ahead of the overload relay (as shown in Figure 2-9-1, circuit a, c, or d), the overload relay current elements should be selected using the full-load motor current and service factor values specified on the nameplate of the motor. Where the capacitor is connected behind the overload relay (as shown in circuit b of Figure 2- 9-1), the overload relay manufacturer's instructions should be followed in selecting current elements, since the overload relay in this case will respond to the phasor sum of the motor and capacitor currents.

Power factor correction capacitors should be switched by a separate contactor (Figure 2- 9-1, circuit d) under any of the following conditions:

a. High-inertia load
b. Open-circuit transition reduced-voltage starting
c. Wye-delta motor
d. Reversing or frequently jogged motor
e. Multispeed motors

Also see MG 2.

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9.3.2 Capacitor Bank Switching

When discharged, a capacitor has essentially zero impedance. For repetitive switching by contactors, sufficient impedance should be connected in series with the capacitor bank to limit the inrush current to not more than the maximum circuit closing inrush current from Table 2-4-17. In many installations, the impedance of connecting conductors may be sufficient for this purpose.

When switching to connect an additional bank, the banks already on the line may be charged and can supply additional available short-circuit current which should be considered when selecting impedance to limit the current.

9.3.3 Limiting Capacitor Surge Current

One method of limiting the surge current is to add inductance in the capacitor conductors. A simple air-core reactor may be made by forming a coil approximately 6 inches in diameter (ID), in each of the capacitor conductors, properly sized for the application. For systems voltages up to 250 volts, six turns have been found to be adequate; and for voltages up to 600 volts, eight turns have been found to be adequate.

9.3.4 Effects of Capacitors on Controller Applications

Where capacitors are connected directly across the terminals of an AC motor, on the load side of the motor overcurrent device, the controllers shall be applied in accordance with this standard. See Part 1.

Because of the resulting reductions in the current passing through the controller, the rating of the motor overcurrent device must be reduced to provide motor overload protection.

The motor manufacturer should be consulted as to the maximum permissible size of the capacitor and the proper rating of the motor overcurrent protective device.

9.4 Controller Comparisons

NEMA Standards Publication No. ICS 2.4 is a comparison of traditional NEMA Class A motor controllers and similar devices built to IEC standards.

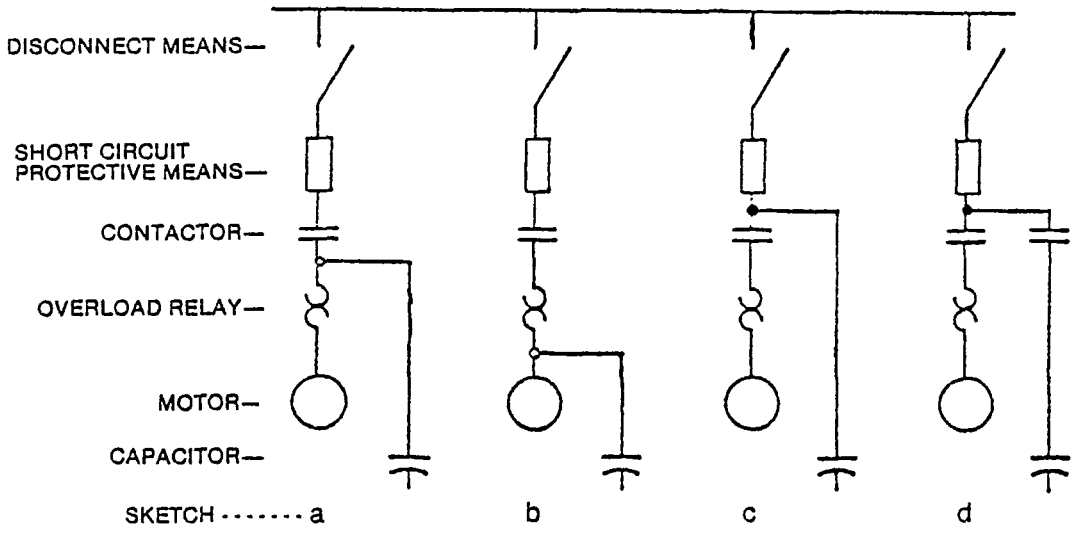


Figure 2-9-1
METHODS OF CONNECTING POWER FACTOR CORRECTION CAPACITORS

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Part 3
NONMAGNETIC MOTOR CONTROLLERS

1 General

1.1 Scope

The standards in this part apply to nonmagnetic controllers and switches rated 600 volts and less, 50 and 60 hertz such as:

a. Class A manually-operated and motor-operated controllers for squirrel-cage and wound-rotor induction motors
b. Pressure switches (specifically includes domestic water pump, air compressor pressure switches)
c. Temperature switches for cooling fans and resistive loads
d. Liquid level or float switches for pump control
e. Drum controllers

1.2 Normative References

The definitions and standards of NEMA Standards Publications No. 250, ICS 1 and ICS 2, Part 1 apply to this part unless otherwise stated.

See ICS 5, Part 3 for additional definitions and construction requirements for the actuators of pressure, temperature and liquid level switches.

2 Definitions

For the purposes of this part, the following definitions apply.

drum controller: An electric controller that utilizes a drum switch as the main switching element.

A drum controller usually consists of a drum switch and a resistor.

drum switch: A switch in which the electric contacts are made on segments or surfaces on the periphery of a rotating cylinder or sector, or by the operation of a rotating cam.

float switch: A liquid level switch which is operated by a buoyant constituent part.

liquid level switch: A switch which is responsive to the level of a liquid.

pressure switch: A switch which is operated by a constituent part and is responsive to fluid (gas or liquid) pressure.

A vacuum switch is a pressure switch which operates primarily at pressure less than atmospheric.

temperature switch: A two-state (ON-OFF) controller which is responsive to the temperature of a sensed medium.

3 Classification

This part contains no classifications.

4 Characteristics and Ratings

4.1 Horsepower and Current Ratings of Manually-Operated and Motor-Operated Controllers

4.1.1 Ratings of Manually-Operated and Motor-Operated Controllers for Integral-Horsepower Induction Motors

The ratings of nonreversing and reversing full-voltage single-speed controllers, with or without motor running overcurrent protection or other auxiliary devices and when mounted in any type of enclosure, shall be:

a. In accordance with Table 3-4-1 for three-phase controllers
b. In accordance with Table 3-4-2 for single-phase controllers

4.1.2 Ratings of Manually-Operated or Motor-Operated Controllers for Fractional-Horsepower Motors

The rating of full-voltage manually-operated controllers, single or double pole, provided with or without running overcurrent protection and enclosed in any type of enclosure for use with fractional-horsepower single-phase motors, shall be 1 horsepower at AC voltages of 115 and 230 volts.

4.2 Ratings of Drum Controllers

4.2.1 Ratings of Drum Controllers for Single-Speed and Multispeed Motors

The ratings of drum controllers for full-voltage single-speed and multispeed induction motors (other than wound rotor) shall be as shown in Table 3-4-3.

4.2.2 Ratings of Manually-Operated Drum Controllers for Wound-Rotor Motors

The horsepower ratings and the number of control points of enclosed alternating-current drum controllers for wound-rotor motors shall be as shown in Tables 3-4-4 and 3-4-5. Continuous ratings apply in all cases where any point on the drum switch will be used for any period exceeding 5 minutes. Intermittent ratings shall be used for crane, hoist or other duty where the running time is not more than 50 percent of the total time and the maximum running time is not more than five minutes.

For starting duty only, the number of control points shall be permitted to be from 8 to 10, and the ampere and horsepower ratings for the 100-ampere to 300-ampere sizes shall be permitted to be doubled provided a contactor of the proper rating is used to shunt the controller on the final point. Under similar conditions for the 600-ampere

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Table 3-4-1
HORSEPOWER (HP) AND LOCKED-ROTOR CURRENT (LRA) RATINGS FOR THREE-PHASE, SINGLE SPEED, FULL-VOLTAGE MANUALLY OR MOTOR-OPERATED CONTROLLERS

Size of Controller	Continuous Current Rating (Amperes)	At 200V–60Hz		At 200V–60Hz		At 380V–60Hz		At 460 V–60 Hz		At 575V–60 Hz		Service-Limit Current Rating* (Amperes)
		HP	LRA	HP	LRA	HP	LRA	HP	LRA	HP	LRA	
M-O	18	3	74	3	70	5	64	5	53	5	42	21
M-1	27	7-1/2	152	7-1/2	140	10	107	10	88	10	70	32

* See Clause 4.1.2 of Part 2

Table 3-4-2
HORSEPOWER (HP) AND LOCKED-ROTOR CURRENT (LRA) RATINGS FOR SINGLE-PHASE, SINGLE SPEED, FULL-VOLTAGE MANUALLY OR MOTOR-OPERATED CONTROLLERS FOR PLUG-STOP, PLUG-REVERSE, OR JOGGING DUTY

Size of Controller	Continuous Current Rating (Amperes)	At 115 V 50 – 60 Hz		At 230 V 50 – 60 Hz		Service-Limit Current Rating* (Amperes)
		HP	LRA	HP	LRA	
M-0	18	1	80	2	65	21
M-1	27	2	130	3	90	32
M-1P	36	3	140	5	135	42

* See Clause 4.1.2 of Part 2

Table 3-4-3
RATINGS OF DRUM CONTROLLERS

Size of Controller	Horsepower at			
	Three Phase*		Single Phase	
	200 or 230 Volts	460 or 575 Volts	115 Volts	230 Volts
D-0	2	2	1	1-1/2
D-1	5	7-1/2	1-1/2	3

* Does not include three-phase constant-horsepower multispeed motors. For these motors, use the ratings given in the single-phase column.

Table 3-4-4
RATINGS OF MANUALLY-OPERATED DRUM CONTROLLERS FOR WOUND-ROTOR MOTOR PRIMARY AND SECONDARY CONTROL*

8-hour Rating, Amperes	Number of Control Points	Horsepower Rating Continuous Duty		Horsepower Rating Intermittent Duty		Service-Limit Current Rating Amperes**
		230 Volts	460 or 575 Volts	230 Volts	460 or 575 Volts	
50	5 or 6	15	25	15	25	58
100	6 or 7	30	50	40	75	115
150	7 or 8	50	100	60	125	173
300	9 or 10	100	200	150	300	345

* Drum Controllers shall open all ungrounded lines of a three-phase primary circuit.

** See Clause 4.1.2. of Part 2.

Table 3-4-5
RATINGS OF MANUALLY-OPERATED DRUM CONTROLLERS FOR WOUND-ROTOR MOTOR, SECONDARY CONTROL ONLY*

8-hour Rating, Amperes	Number of Control Points	Horsepower Ratings at 230, 460 or 575 Volts	Service-Limit Current Rating, Amperes**
100	11	50	115
150	11	100	173
300	11	300	345
600	11	750	690

* Drum controllers for starting duty only.

** See Clause 4.1.2 of Part 2.

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size, the rating shall be permitted to be increased to 1000 amperes and 1250 horsepower.

4.2.3 Ratings of Motor-Operated Drum Controllers for Wound-Rotor Motors

The ratings of alternating-current motor-operated drum controllers for use in the secondary circuits of wound-rotor motors shall be as shown in Table 3-4-6, all speed points being balanced.

4.3 Contact Ratings of Pressure, Temperature and Liquid-Level Motor Controllers

The ratings of these switches where intended for use as motor controllers shall be in terms of horsepower and continuous current for one or more utilization voltages.

The ratings of these switches where used as an integral part of engineered motor and controller combinations shall be in terms of horsepower and continuous current or motor full-load and locked-rotor current for one or more utilization voltages.

The ratings may be on the basis for two poles controlling a three-phase motor or one pole controlling a single-phase motor.

Table 3-4-6
RATINGS OF MOTOR-OPERATED DRUM CONTROLLERS FOR SECONDARY CIRCUITS OF WOUND ROTOR MOTORS

8-hour Rating, Amperes	Number of Speed-Regulating Points	Service-Limit Current Rating, Amperes
300	13	345
300	20	345
600	13	690
600	20	690

4.4 Ratings of Resistors for Motor Secondary Circuits

Resistors for the secondary circuits of wound-rotor motors used with manually-operated controllers, shall be rated as follows:

a. 50 Horsepower and Less—Class No. 114 or 115
b. More than 50 Horsepower—Class No. 132, 133, 134 or 135

See ICS 9, Part 2 for resistor classes.

5 Product Marking, Installation and Maintenance Information

See ICS 1.3 for preventive maintenance instructions.

6 Service and Storage Conditions

See ICS 1, Clause 6.

7 Construction

7.1 Current Carrying Capacity of Resistors

See ICS 9, Part 2.

7.2 Face-Plate Type Controllers

Face-plate type controllers shall be enclosed.

7.3 Drum Controller Conduit Connections

Drum switches shall include a provision for conduit connections.

8 Performance Requirements and Tests

See Clause 8 of ICS 1 and Clause 8 of Part 1.

9 Application

Pressure, temperature and liquid level switches which are rated for motor applications should be used with motors having integral thermal protectors or an equivalent means for providing running overcurrent protection for the motor branch circuit. It should be noted that when two pole switches are used to control three-phase motors only two lines are disconnected when the switch is open and the motor terminal box contains live parts unless the branch circuit disconnect device is also open.

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Part 4
OVERLOAD RELAYS

1 General

1.1 Scope

The standards in this part apply to overload relays that monitor motor current. They may be mounted separately or combined with contactors (motor controllers) used in industrial control pplications.

1.2 Normative References

The definitions and standards of ICS 1, and ICS 5, Part 1 apply to this part unless otherwise stated.

2 Definitions

For the purposes of this part, the following definitions apply:

(* indicates definition from ANSI/IEEE Standard 100.)

algorithm:* A prescribed set of well-defined rules or processes for the solution of a problem in a finite number of steps, for example, a full statement of an arithmetic procedure for evaluating sine x to a stated precision.

ambient temperature compensated (overload relay): A qualifying term applied to an overload relay to indicate that its ultimate current remains essentially unchanged over a designated range of ambient temperatures.

ambient temperature sensitivity (overload relay): An expression of performance which defines the variations in its ultimate current over a designated range of ambient temperature.

automatic reset (overload relay): A term used to describe an overload relay having an integral function that independently causes the overload relay to be reset.

current element (overload relay): The part of an overload relay that determines the value of current which causes the relay to operate (trip). Current elements of thermal overload relays are referred to as heater elements.

current rating (overload relay): The minimum value of continuously applied current which is expected to cause all like relays to operate (trip) under designated conditions. This value, for an individual relay, may be equal to or exceed its ultimate current under these conditions.

heater element (thermal overload relay): The part of a thermal overload relay that is intended to produce heat when conducting current. Heater elements are sometimes referred to as heaters, thermal units, current elements, or heating elements.

induction-disc relay: A protective device that includes a rotating disc in which currents are induced by permanent magnets and electromagnets in such a manner that the rotation of the disc to operate contacts is related to a selected inverse time function.

instantaneous trip (overload relay): A qualifying term indicating that no delay is purposely introduced in the tripping action of the relay.

integrated motor monitor: A single solid-state device that provides a multiplicity of motor monitoring functions, one of which is overload protection, by sensing current components and using an algorithm to determine when it should provide a signal to alarm or trip, or both.

inverse time (overload relay): A qualifying term indicating that a delay is purposely introduced in the tripping action of the relay. The delay decreases as the magnitude of the current increases.

limit of self protection (overload relay): The maximum current value that an overload relay can respond to without sustaining damage that will impair its function.

manual reset (overload relay): A term used to describe an overload relay that requires deliberate human actuation in order to be reset.

operating memory: A characteristic of an overload relay that considers the cumulative heating effect in the motor circuit resulting from motor operation or overload, and the cooling effect after the motor circuit is deenergized.

operating memory, nonvolatile: An operating memory that is not lost if power to the relay is interrupted for a short period of time (See 8.8, Operating Memory Test for an Inverse-Time Overload Relay).

overcurrent: Any current in excess of the rated continuous current of equipment or the ampacity of a conductor. It may result from motor starting, overload, short circuit or ground fault.

overload: Operation of equipment in an electrically undamaged circuit in excess or normal, full-load rating, or of a conductor in excess of rated ampacity which, if persisting for a sufficient length of time, would cause damage or overheating. A fault, such as a short circuit or ground fault or a loss of phase, is not an overload.

overload relay: An overcurrent relay which operates (trips) at a predetermined value of over-current to provide a signal or to cause disconnection of the load from the power supply, or both.

An overload relay is intended to protect the motor branch circuit conductors, the motor control apparatus and the motor(s) against overcurrent. It may not necessarily protect itself.

overload relay class: A classification of an overload relay time-current characteristic by means of a number which designates the maximum time in seconds at which it will operate (trip) when carrying a current equal to 600 percent of its current rating.

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solid-state overload relay: An overload relay which senses overcurrent and performs a control function by means of a semiconductor circuit. A solid-state overload relay may have a semiconductor or a contact output.

thermal overload relay: An overload relay that operates (trips) by means of a thermally responsive system.

time-current characteristic (overload relay): An expression of performance which defines the operating time of an overload relay at various multiples of its current rating.

trip free (overload relay): A qualifying term applied to an overload relay to indicate that its operation is independent of and nonvoidable by the manual reset means.

ultimate current: The minimum value of continuously applied current that will cause an overload relay to operate (trip).

3 Classification

3.1 Inverse-Time Overload Relays

3.1.1 Overload Relay Class Designations

When an inverse-time overload relay is described by time-current characteristics, it shall be designated by a class number indicating the maximum time in seconds at which it will operate (trip) when carrying a current equal to 600% of its current rating. The class number applies with balanced overcurrent in all active phases. A Class 20 relay will operate (trip) in 20 seconds or less, a Class 30 relay will operate in 30 seconds or less, and a Class 10 relay will operate (trip) in 10 seconds or less.

3.1.2 Inverse-Time Overload Relay Categories

Inverse-time overload relays are categorized by their ability to consider the cumulative heating effect in the motor circuit as a result of motor operation or overload. This characteristic, called operating memory, may be either volatile or nonvolatile.

CATEGORY	CAPABILITY
A	nonvolatile operating memory
B	volatile operating memory
C	no operating memory

3.2 Instantaneous Overload Relays

Instantaneous overcurrent relays ("jam" relays) are used in applications in which the overcurrent represents a load condition requiring instant removal of the motor from the line. The time or current, or both to operate the relay must be such that normal overcurrents, such as during normal motor starting, do not cause nuisance tripping. This function may also be accomplished by disabling the "jam" relay during start-up.

4 Characteristics and Ratings

4.1 Overload Relay Types

4.1.1 Overload Relays That Respond to Current Heating Effect

Overload protection devices that respond to the heating effect of the motor line current include thermal and certain solid-state overload relays. Thermal overload relays use the motor line current to produce heat within themselves at a designed rate to simulate load and conductor heating. Solid-state overload relays of this type monitor motor line currents and determine with semiconductor circuits the heating effect of these currents on the load and conductors.

All thermal overload relays have an operating memory, i.e., they respond as if they remember that the load they are protecting has been operating at some rate and may not be cold when returned to service after an overload. Solid-state overload relays may have an equivalent operating memory. The operating function can be provided in various ways, such as by charging a capacitor or altering the count in a register of a microprocessor.

4.1.2 Overload Relays That Respond to Current Magnitude

Protection devices that respond to the magnitude of the line current include magnetic, induction-disc, and certain solid-state relays. Such overload relays may be instantaneous-trip or inverse-time.

4.1.2.1 Magnetic Type

Magnetic overload relays may be instantaneous-trip or inverse-time. In inverse-time overload relays the movement of the plunger, attracted by a magnetic field, is slowed by dashpot action.

4.1.2.2 Induction-Disc Type

Induction-disc relays provide adjustable inverse-time functions by varying the position or effect of the permanent magnets or electromagnets, or both on the induction disc which must rotate to cause the relay to trip.

4.1.2.3 Solid-State Type

Solid-state overload relays may be instantaneous-trip or inverse-time. Inverse-time overload relays may have circuitry or a program to obtain the inverse-time function.

4.2 Overload Relay Current Rating

The current rating of an overload relay shall be expressed in amperes at an ambient temperature of 40°C.

An overload relay may have different current ratings where used as an open-type device, or where mounted in an enclosure, or where used in combination with other equipment within a similar enclosure. The ambient temperature of 40°C for current rating assignment of enclosed devices shall refer to the measured temperature of the air which surrounds the enclosure.

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4.3 Overload Relay Time-Current Characteristics

The time-current characteristics of inverse-time overload relays in a 40°C ambient temperature are preferably expressed as the maximum operating times in seconds under the designated conditions associated with the current rating, at current values corresponding to multiples of the current rating. Curves such as minimum operating times may also be shown. All curves shall be identified. The time-current curve shall not be shown beyond the limit of self protection.

The preferred method for displaying these performance curves shall be time in seconds as ordinate and multiples of current rating as abscissa, plotted on a full logarithmic coordinate format as shown in the example in Figure 4-4-1.

Where the current setting is adjustable, these performance curves should be given for each end of the adjustment range. If the time characteristics are adjustable, they should also be given for each end of the adjustment range.

4.4 Overload Relay Limit of Self Protection

The limit of self protection of an overload relay at a 40°C ambient temperature shall be expressed by the assigned whole-number multiple of its current rating.

An overload relay should not be subjected to these current levels frequently.

4.5 Overload Relay Ambient Temperature Sensitivity

The ambient temperature sensitivity of an overload relay shall be expressed as the percent change in ultimate current per 10°C change of ambient temperature, between 25°C and 50°C.

The range of ambient temperature qualifying the percent change may be outside the application limits for continuous-duty operation and is only intended to provide the information necessary to predict the performance that can be expected under intermittent or abnormal operating conditions.

The ambient temperature sensitivity value may be applied to the current rating to determine the approximate ultimate current at other ambient temperatures.

4.6 Control-Circuit Contact Ratings

The rating of the contacts of an overload relay which operate in a control circuit shall be in accordance with ICS 5, Table 1-4-1, for the AC ratings and ICS 5, Table 1-4-2, for DC ratings.

4.7 Solid-State Control Circuit Ratings

Overload relays with semiconductor switching elements which operate in a control circuit shall be rated in accordance with ICS 5, Table 1-4-4 for the AC applications and ICS 5, Table 1-4-5 of for DC ratings.

4.8 Solid-State Overload Relays with External Control Power Source

Where an overload relay uses an external control power source, the relay shall open the normally-closed contacts or switching element when control power is removed.

4.9 Line Current Relationship in Polyphase Circuits

Instantaneous-trip and inverse-time overload relays may respond to the relationship of line currents in each phase. This relationship may include phase-loss, phase-unbalance and phase-angle functions. The response characteristics of overload relays to this relationship are not included in this standard.

5 Product Marking, Installation and Maintenance Information

5.1 Identification of Interchangeable Current Elements and Product Information

Interchangeable current elements shall bear identification which is visible after the apparatus is installed and wired. Information relating the identification to the complete device shall be furnished and shall include:

a. The current rating or the assigned motor full-load current or range of currents and frequency, when applicable
b. Instructions for converting assigned motor full-load current to the relay current rating
c. Maximum available fault current and recommendations for fault-current protection where such protection is not included with the equipment and where the requirements are more restrictive than those of the National Electrical Code
d. Overload relay class if other than Class 20
e. Overload relay category if other than Category A
f. Range of adjustment if adjustment is provided
g. Control circuit ratings
h. Power supply requirements (volts, amperes, hertz) when applicable
i. Power conductor size and insulation temperature rating, expressed in one of two methods:
    1. By minimum insulation temperature rating (e.g., 75°C) and conductor size for each current element
    2. By minimum insulation temperature rating and instructions permitting the use of conductors with a higher temperature rating, provided that the conductor size is selected on the basis of the ampacity of conductors with the minimum insulation temperature rating. For example, if 75°C is the minimum conductor insulation rating specified, 90°C conductors may be used, provided that the conductor size is selected

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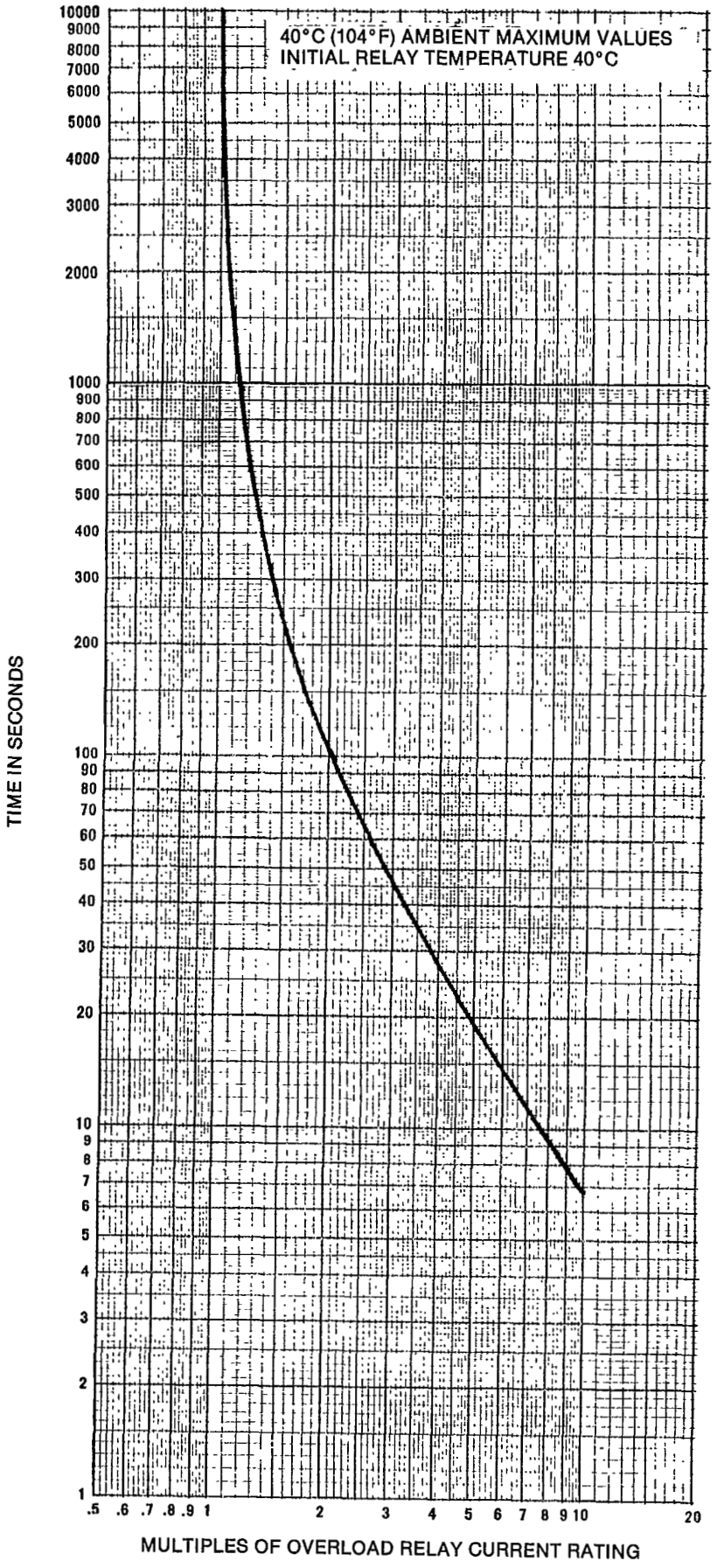


Figure 4-4-1
OVERLOAD RELAY TIME-CURRENT CHARACTERISTICS—EXAMPLE

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from the 75°C column of Table 310-16 of the National Electrical Code (NFPA 70 "NEC")

j. Tightening torque for user connections

5.2 Identification of Overload Relays Using Fixed or Noninterchangeable Current Elements

An overload relay with fixed or noninterchangeable current elements shall meet the requirements of 5.1 except that the identification of the current element may be marked on the overload relay.

5.3 Preventive Maintenance Guide

See ICS 1.3 for preventive maintenance instructions.

6 Service and Storage Conditions

See ICS 1, Clause 6.

7 Construction

7.1 Selectable Functions and Settings

Where an overload relay provides functions or settings to be selected or adjusted by the user (e.g., overload relay class, phase unbalance, motor current, reset mode, etc.), these functions or settings shall be visible from the front when the overload relay or integrated motor monitor is mounted in its normal operating position.

7.2 Trip Indication

An overload relay may include a means to show that it is tripped.

7.3 Resetting

An overload relay shall be capable of being reset. Resetting may be accomplished automatically or manually. Overload relays shall be of the trip-free type.

If an overload relay is constructed so that it can be reset by the momentary removal and reapplication of power, instructions for power application should be included.

8 Performance Requirements and Tests

8.1 Verification Test for Overload Relay Current Rating and Time-Current Characteristics

8.1.1 Test Conditions

a. Tests shall be conducted in an ambient temperature of 40°C±1°C. The overload relay shall be allowed to reach thermal equilibrium with the specified ambient temperature before proceeding with each test.

b. Tests shall be conducted in a manner which simulates the intended service conditions: this includes the designated conditions for the assignment of the current rating, that is, whether the relay is a separate device or a part of a motor controller, and whether it is open or enclosed.

c. Relays designated as "ambient temperature compensated" shall be tested in ambient temperatures of 25°C and 50°C, as well as 40°C.

d. The power source shall be single phase, 60 hertz with means for maintaining a sine-wave current of an essentially constant rms value, unless the relay must be tested using another power system.

e. Current measurements shall be accurate within one percent of the measured value.

8.1.2 Test Connections

a. Conductors for Relays Marked for Full-load Current

Conductors for the external wiring to the overload relay (or associated equipment), considered to be user connections, shall have a minimum length of 4 feet (1.2 meters) per terminal. The wire shall be of the smallest size having an ampacity of at least 125 percent of the maximum motor full-load current listing for the overload relay, the overload relay setting, or the overload relay current element. The wire shall be selected from the 75°C column of Table 310-16 of National Electrical Code, unless otherwise specified by the manufacturer.

b. Conductors for Relays Marked with Current Rating

Conductors for the external wiring to the overload relay (or associated equipment), considered to be user connections, shall have a minimum length of 4 feet per terminal. The wire shall be the smallest size having an ampacity at least equal to the current rating of the relay, the overload relay setting, or the overload relay current element. The wire shall be selected from the 75°C column of Table 310-16 of National Electrical Code, unless otherwise specified by the manufacturer.

c. Schematic Diagram

The wiring for three-phase devices shall be in accordance with the typical schematic diagram shown in Figure 4-8-1 for single-phase and DC sources and as shown in Figure 4-8-2 for three-phase test sources. The wiring for single-phase devices shall be in accordance with the manufacturer's instructions.

d. Control Circuit

To avoid possible damage to the relay, it is recommended that the test circuit be arranged so as to assure the disconnection of the current source when the overload relay operates (trips).

8.1.3 Test Procedure

a. A single-pole relay or a three-pole relay connected as a single-pole relay shall be tested at 100, 200 and 600 percent of the relay current rating.

b. Three single-pole relays, each with its own current element and trip mechanism, or a three-pole relay with three current elements and a single trip

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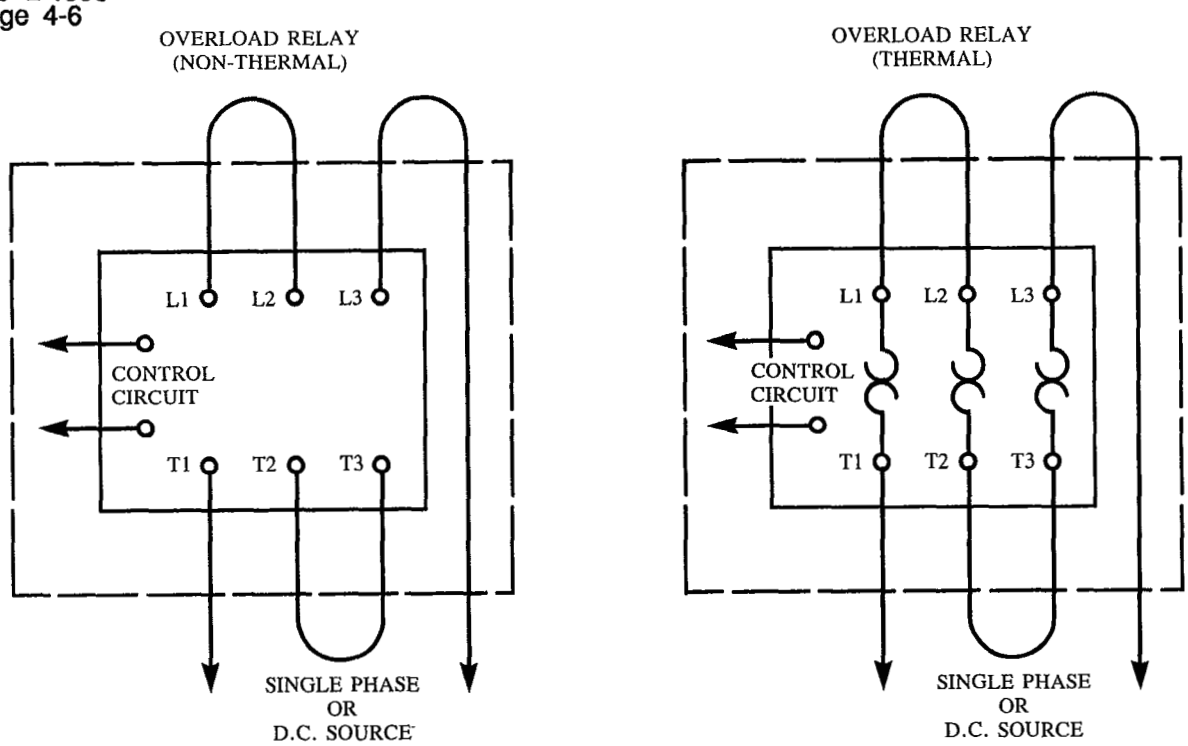


Figure 4-8-1
SCHEMATIC DIAGRAM OF THREE PHASE OVERLOAD RELAY
TEST CONNECTIONS FOR SINGLE PHASE AND D.C. TEST SOURCES

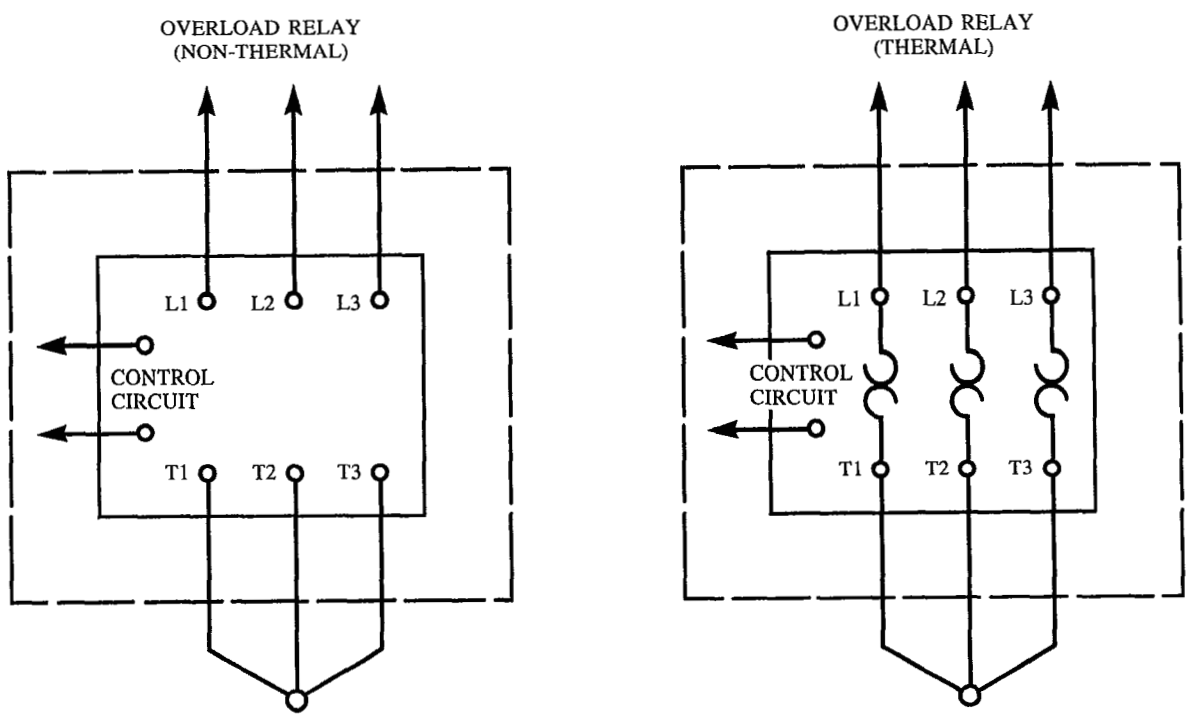


Figure 4-8-2
SCHEMATIC DIAGRAM OF THREE PHASE OVERLOAD RELAY
TEST CONNECTIONS FOR THREE PHASE SOURCE

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mechanism, intended for three-phase circuits, shall be tested at:

1. 100 percent of the relay's current rating with three current elements connected
2. 200 percent of the relay's current rating with two current elements connected
3. 600 percent of the relay's current rating with two current elements connected
4. 600 percent of the relay's current rating with three current elements connected

c. An adjustable relay with interchangeable current elements and means for adjustment in percent of its current rating shall be set at the 100 percent mark on the adjustment scale and subjected to the test described in a) or b), depending on the intended application and number of relays involved. In addition, an adjustable relay shall be tested at its high and low adjustment points, such as the 120 and 80 percent marks, at 200 percent of its current rating to determine that the time of operation will be longer and shorter, respectively, than the operating time when the relay is subjected to the same test with the adjustment set at the 100 percent mark on the adjustment scale.

d. An adjustable relay arranged to cover several current ratings (trip currents) shall be tested at 100, 200 and 600 percent at its minimum, midpoint and maximum current ratings.

8.1.4 Performance

When tested as described above, an overload relay shall perform as shown in Table 4-8-1.

8.2 Verification Test for Limit of Self-Protection

8.2.1 Test Conditions

The test conditions shall be the same as those specified in 8.1.1 except that "ambient temperature compensated" relays may be tested at 40°C only.

8.2.2 Test Procedure

A single test shall be conducted for the limit of self protection assigned to an overload relay.

The magnitude of the test current (self-protection limit current) is determined by multiplying the current rating of the overload relay by the multiplier assigned as its limit of self protection.

8.2.3 Test Connections

Test connections shall be the same as those specified in 8.1.2.

The test circuit shall be arranged to assure that tripping of the overload relay will immediately cause the overload relay to be disconnected from the current source.

8.2.4 Performance

When tested at its self-protection limit current, an overload relay shall operate (trip) without sustaining damage that will impair its performance. An overload relay which has been subjected to this test shall be considered to conform to the requirements of this standard if it can subsequently be shown that it meets the requirements of the design test for current rating described in 8.1.

8.3 Verification Test for Overload Relay Ambient Temperature Sensitivity

8.3.1 Test Conditions

Test conditions shall be the same as those specified in 8.1.1, except that tests shall be conducted at 40°C and other specified ambient temperatures.

8.3.2 Test Connections

Test connections shall be the same as those specified in 8.1.2.

8.3.3 Test Procedure

The ultimate currents shall be determined at the ambient temperatures under consideration.

Table 4-8-1
OVERLOAD RELAY PERFORMANCE

Test Current as Percent of Overload Relay Rating	Quantity of Poles Connected		Maximum Trip Times			
	3 Pole Relays	1 Pole Relay	Class 10	Class 15	Class 20	Class 30
100%	3	1	----------ULTIMATELY*----------			
200%	2	1	----------8 MINUTES----------			
600%	2 and 3	1	10 Sec.	15 Sec.	20 Sec.	30 Sec.

* Experience indicates that two to four hours is generally sufficient to verify this value. Systems which have large masses may require additional time.

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8.3.4 Performance

When the ultimate currents are determined in this manner, the ambient temperature sensitivity of the overload relay shall not exceed the designated value.

8.4 Overload Relay Short-Time Capability

A new overload relay shall be capable of meeting the short-time operating and short-time surge capability requirements for controllers shown in Clause 8 of Part 2.

8.5 Control-Circuit Output

The contacts or solid-state switching element of an overload relay shall perform in accordance with ICS 5, Part 1.

8.6 Electrical Noise Test for Solid-State Devices

Solid-state overload relays and integrated motor monitors for sensing or switching shall not malfunction when subjected to the electrical noise test procedures of ICS 1.

8.7 Impulse Withstand Test for Solid-State Devices

Solid-state overload relays and integrated motor monitors using semiconductor elements shall not malfunction during and after being subjected to the impulse withstand test procedures of ICS 1, Annex A of ICS 1 for installation (overvoltage) category III applied to the power circuit, and for installation (overvoltage) category II or I applied to the control circuit and power supply terminals. Energy levels for the impulse test are under consideration.

8.8 Operating Memory Test for an Inverse-Time Overload Relay

An inverse-time overload relay that includes an operating memory shall be tested to verify the existence of a memory by applying 600 percent of rated current through all active phases, as shown in Figure 4-8-2 until it operates (trips). Reset as soon as possible. The time to trip and time to reset shall be recorded. The 600 percent current shall be reapplied and the time to trip recorded. The control power (if so equipped) shall be removed for 1.5 minutes after tripping, reapplied, and then the relay reset as soon as possible. The 600 percent current control power shall be applied for the third time and the time to trip recorded.

If, in Test No. 2, the trip time T2 is not greater than 85 percent of the trip time T1 of Test No. 1, the relay is considered to have an operating memory.

If, in Test No. 3, the trip time T3 is not greater than 85 percent of the trip time T1 in Test No. 1, the relay is considered to have a nonvolatile operating memory.

OPERATING TEST PROCEDURE

Test No.	Percent Rated Current	Trip Time (Seconds)	Procedure Following Trip
1	600	T1	Reset as soon as possible.
2	600	T2	Remove control power for 1.5 minutes. Reapply control power. Reset as soon as possible.
3	600	T3	End of test.

9 Application

9.1 Current Rating and Time-Current Characteristics

The current rating and time-current characteristics of an overload relay should be coordinated with the components of a branch circuit selected in accordance with the National Electrical Code.

9.2 Limit of Self Protection

The current corresponding to the limit of self protection of an overload relay should be greater than the locked-rotor current of the motor it is intended to protect.

9.3 Ambient Temperature Sensitivity

The ambient temperature sensitivity provides the means to modify the selection of overload relays to accommodate a difference in ambient temperatures between the overload relay and motor that may exist on some applications.

9.4 Cautions on the Use of Automatic Reset

Automatic reset of overload relays is a convenience in many installations and a necessity in some. However, the use of automatic reset should be considered only if: a) the motor circuit will remain open when the overload relay contacts reclose, or b) automatic restarting will not create a hazard.

An automatic-reset overload relay does not necessarily provide protection against overheating of a motor and its branch-circuit components from a persisting overload condition that causes repetitive tripping and resetting of the relay. It may be necessary to provide means for delaying motor restarting or limiting the number of trip-reset cycles.

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9.5 Polyphase Motors Under Single-Phase Operating Conditions

Overload protection which is provided by overcurrent units having current elements in each phase of a polyphase motor and which provides protection under polyphase operating overloads may not provide the same degree of protection when the same motor is operating under single-phase conditions.

9.6 Coordination with Fault-Current Protection

9.6.1 Fault-Current Protection

An overload relay should be protected against fault currents by a device of a type and rating in accordance with Clause 5.1 item c.

9.6.2 Limit of Self Protection

At the current value corresponding to the self-protection limit of the overload relay, the fault-clearing time of the branch-circuit protective device should not exceed the operating (trip) time of the overload relay. When this comparison is based on mean values, a margin for safety should be allowed to account for possible variations in operating (trip) times.

9.6.3 Operating Overloads

Under operating overload conditions it is desirable for the overload relay to operate (trip) before the branch-circuit protective device can open the circuit. It may not be possible to obtain this degree of coordination with all types of branch-circuit overcurrent devices.

9.7 Application with Current Transformers

The current rating and the performance characteristics of an interconnected current transformer and overload relay will not necessarily be the same as those of the overload relay alone and shall be determined by the primary current of the current transformer.

9.8 Control-Circuit Contact Rating

The control-circuit contact rating of an overload relay should be adequate for the connected load in the particular control-circuit arrangement.

9.9 Short-Duration Overcurrent Effect

Overcurrents of short duration, such as those that occur during motor starting, are expected and do not cause excessive heating or damage to the motor, motor branch-circuit conductors, or motor control equipment if they do not occur frequently.

9.10 Overload Relay Limitations

Most devices offered to protect motors from overheating are designed to monitor currents from a fixed-frequency supply. Motors operating on a variable-frequency supply voltage can be overheated by internal currents and loss of cooling at low speeds without appearing to be drawing excessive current. Conventional overload relays should not be used in variable-frequency motor branch-circuits unless appropriate compensating steps are taken.

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Part 5
DC GENERAL-PURPOSE CONSTANT-VOLTAGE CONTROLLERS

1 General

1.1 Scope

The standards in this Part apply to Class B manual and magnetic controllers used with direct-current motors rated 600 volts or less.

1.2 Normative References

The definitions and standards of ICS 1 and ICS 2, Part 1 apply to this Part unless otherwise stated.

2 Definitions

For purposes of this Part the following definition applies:

Class B controllers: DC air-break manual or magnetic controllers for service at 600 volts or less.

They are capable of interrupting operating overloads but not short circuits or faults beyond operating overloads.

3 Classification

3.1 Types of Full-Voltage Class B Magnetic Controllers

The types of full-voltage Class B magnetic controllers shall be:

a. An enclosed nonreversing controller consisting of a two-pole line contactor and an overload relay and with provision for separate mounting of the pushbutton.
b. An enclosed nonreversing controller consisting of a two-pole line contactor and an overload relay and with the pushbutton mounted in the cover.
c. An enclosed reversing controller consisting of a two-pole line contactor and an overload relay and with provision for separate mounting of the pushbutton.
d. An enclosed reversing controller consisting of a two-pole line contactor and with provision for separate mounting of the pushbutton.

3.2 Reduced-Voltage Class B Magnetic Controllers for General-Purpose Applications

An enclosed nonjogging nonreversing Class B controller for motors having a 2 to 1, or less, speed range by field control and having a maximum rating of 5 horsepower at 115 volts and 10 horsepower at 230 volts shall include:

a. A single-pole line contactor
b. Necessary accelerating means
c. A single-element overload relay
d. A starting resistor (Class 115 or 116)
e. Provision for a separately mounted pushbutton

3.3 For Motors Having a 2 to 1 or Less Speed Range by Field Control

An enclosed jogging-duty controller, Sizes 1 through 9 (see 4.4) for motors having a 2 to 1 or less speed range by field control shall include:

a. **For Nonreversing Controllers without Dynamic Braking:**
   1. A single-pole line contactor
   2. One to seven accelerating contactors with accelerating means
   3. A single-element overload relay
   4. A starting resistor (Class 135 or 136)
   5. Provision for a separately mounted pushbutton
b. **For Nonreversing Controllers with Dynamic Braking:**
   1. The same equipment as the controller described in par. a
   2. A dynamic-braking contactor or the equivalent
   3. A dynamic-braking resistor
c. **For Reversing Controllers with Dynamic Braking:**

   The same equipment as the controller described in par. b, but with a set of reversing contactors instead of the line contactor.

3.4 For Motors Having a Speed Range in Excess of 2 to 1 by Field Control

An enclosed jogging-duty controller, Sizes 1 through 9 (see 4.4) for motors having a speed range in excess of 2 to 1 by field control shall include:

a. **For Nonreversing Controllers without Dynamic Braking:**
   1. A single-pole line contactor
   2. One to seven accelerating contactors with accelerating means
   3. A single-element overload relay
   4. A starting resistor (Class 135 or 136)
   5. Means for full-field starting
   6. Field acceleration means
   7. Provision for a separately mounted pushbutton
b. **For Nonreversing Controllers with Dynamic Braking:**
   1. The same equipment as the controller described in par. a
   2. A dynamic-braking contactor or the equivalent
   3. A dynamic-braking resistor

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c. For Reversing Controllers with Dynamic Braking:

The same equipment as the controller described in par. b, but with a set of reversing contactors instead of the line contactor.

4 Characteristics and Ratings

4.1 Horsepower Ratings of DC Drum Switches

The ratings of reversing and nonreversing drum switches shall be in accordance with Table 5-4-1.

Eight-hour ratings shall be used in all cases where any point on the drum switch is in the circuit for any period exceeding 5 minutes. Intermittent ratings shall be used for crane, hoist or other duty where the running time does not exceed 50 percent of the total time and the maximum running time does not exceed 5 minutes.

4.2 Horsepower Ratings of Full-Voltage Manually Operated DC Controllers

The horsepower ratings of full-voltage manually operated controllers (including reversing starter controllers), with or without overload relay or other auxiliary devices and enclosed in any type enclosure, shall be in accordance with Table 5-4-2.

4.3 Horsepower Ratings of Full-Voltage DC Magnetic Controllers

The horsepower ratings of full-voltage magnetic controllers shall be in accordance with Table 5-4-3.

4.4 Horsepower Ratings of Reduced-Voltage DC Magnetic Controllers

The horsepower ratings and the number of accelerating contactors of the controllers described in 3.3 shall be in accordance with Table 5-4-4.

Table 5-4-1
DC DRUM SWITCH RATINGS

8-hour Rating Amperes	8-hour Ratings Horsepower Rating at 115 Volts	8-hour Ratings Horsepower Rating at 230 Volts	Intermittent-duty Ratings Horsepower Rating at 115 Volts	Intermittent-duty Ratings Horsepower Rating at 230 Volts
50	5	10	7-1/2	15
100	10	25	15	30
150	20	40	25	50
300	40	75	50	100

Table 5-4-2
MANUALLY OPERATED DC CONTROLLER RATINGS

Size of Controller	8-hour Open Rating, Amperes	Horsepower Rating at 115 Volts	Horsepower Rating at 230 Volts
0	15	1	1-1/2
1	25	1-1/2	2

Table 5-4-3
FULL-VOLTAGE MAGNETIC DC CONTROLLER RATINGS

Size of Controller	8-hour Open Rating, Amperes	Horsepower at 115 Volts	Horsepower at 230 Volts
0	15	1	1
1	25	1-1/2	2

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Table 5-4-4
REDUCED VOLTAGE MAGNETIC DC CONTROLLER RATINGS

Size of Controller and Contactor	8-hour Open Rating, Amperes	115 Volts		230 Volts		550 Volts	
		Horse-power Rating	Number of Accelerating Contactors	Horse-power Rating	Number of Accelerating Contactors	Horse-power Rating	Number of Accelerating Contactors
1	25	3	1	5	1	. . .	. . .
2	50	5	2	10	2	20	2
3	100	10	2	25	2	50	2
4	150	20	2	40	2	75	3
5	300	40	3	75	3	150	4
6	600	75	3	150	4	300	5
7	900	110	4	225	5	450	6
8	1350	175	4	350	5	700	6
9	2500	300	5	600	6	1200	7

When a motor has different horsepower ratings at different speeds, the controller rating shall apply to the maximum horsepower rating of the motor.
Line, reversing and final-accelerating direct-current contactors shall be selected in accordance with the above table.
Intermediate accelerating contactors shall be selected so that the 8-hour open rating will be not less than 0.25 x the accelerating peak.
These controllers may be used at their rating with motors of comparable rating provided that the motor is operated within its name plate rating or within a service factor rating not greater than 1.15 times its nameplate rating. If the motor is to be operated at a service factor rating in excess of 1.15 but within standard NEMA service factors, it is recommended that a controller having the next higher horsepower rating be used.

5 Product Information, Installation and Maintenance

See ICS 1.3 for preventive maintenance instructions.

6 Service and Installation Conditions

See ICS 1, Clause 6.

7 Construction

7.1 Manual Controllers

Face-plate-type manual controllers shall be enclosed.

7.2 Manual Speed Regulators

Face-plate-type manual speed regulators shall have enclosed face plates.

7.3 Resistor Classification for Manual Controllers

Resistor classifications for DC manual controllers shall be:

a. For Controllers Rated 50 Horsepower and Less—Class No. 114 or 115
b. For Controllers Rated More than 50 Horsepower—Class No. 132, 133, 134 or 135

See ICS 9, Part 2 for resistor class.

8 Performance Requirements and Tests

8.1 Short-Time Surge Capability for Class B Controllers

A new Class B controller shall be capable of meeting the requirements of Clause 8 of Part 1 at 15 times the current corresponding to the horsepower rating for 1 second.

For convenience of testing, the duration of the surge capability test shall be permitted to be shortened (to not less than 0.9 seconds) in order to suit the available test current provided that the value of the I^2t (Joule Integral) is maintained.

8.2 Circuit Opening Test

Class B controllers and direct-current manual starting rheostats shall be capable of opening the circuit on the first point with the motor at rest.

9 Application

Some motor fields may not be able to withstand continuous excitation at full voltage with the motor at rest. In this case, a field protective (economizer) relay is recommended.

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Part 6
AC COMBINATION MOTOR CONTROLLERS

1 General

1.1 Scope

The standards in this part apply to AC combination motor controllers rated 600 volts or less, rated in horsepower or kilowatts or motor full-load current (FLC) and locked-rotor current (LRA). They also apply to:

a. Specific-purpose magnetic controllers and related control equipment to meet the specific requirements of that portion of the petroleum industry concerned with automatic oil field operation
b. Specific-purpose magnetic controllers and related control equipment to meet the specific requirements for automatic irrigation pump controllers

1.2 Normative References

The definitions and standards of NEMA Standards Publication No. 250, ICS 1, ICS 6 and ICS 2, Part 1 apply to this part unless otherwise stated.

2 Definitions

combination controller (600 volts or less): A magnetic controller with additional externally operable disconnecting means contained in a common enclosure. The disconnecting means may be a circuit breaker or a disconnect switch.

Combination starters are specific forms of combination controllers.

3 Classification

Types of combination motor controllers

This standard applies to combination motor controllers of the following types:

a. Full voltage, nonreversing
b. Full voltage, reversing
c. Full voltage, two speed, two winding
d. Full voltage, two speed, one winding
e. Part winding, nonreversing
f. Wye delta, single step, nonreversing
g. Reduced voltage, single step, nonreversing

4 Characteristics and Ratings

4.1 Ratings of Combination Motor Controllers

4.1.1 Voltage Rating

The voltage ratings of combination motor controllers shall be in accordance with ICS 1, Clause 4.

4.1.2 Range of Operating Voltage

The range of operating voltage of combination motor controllers shall be in accordance with Clause 8 of Part 1.

4.1.3 Magnetic Motor Controllers

The ratings of magnetic motor controllers used in combination motor controllers shall be in accordance with Part 2.

4.2 Oil Field Pump Controllers

The ratings of combination oil field controllers shall be the same as those shown in Part 2 for Sizes 00 through 5, for 600 volts or less, three-phase.

4.3 Irrigation Pump Controllers

The ratings of combination irrigation pump controllers shall be the same as those shown in Part 2 for motors rated in horsepower or rated only in full-load and locked-rotor current for Sizes 1 through 5, for 600 volts or less.

4.4 Short-Circuit Current Ratings of Class A Combination Motor Controllers

Class A combination controllers (with a specified short circuit protection device) shall have one or more short-circuit current ratings expressed in maximum available fault current (rms symmetrical amperes) at the rated system voltage. The power factor (X/R ratio) shall be as specified in UL 508. Standard short-circuit current ratings are shown in Table 2-4-16.

5 Product Marking, Installation and Maintenance Information

5.1 Preventive Maintenance Guide

See NEMA Standards Publication ICS 1.3 for preventive maintenance instructions.

5.2 Specific Maintenance Instructions

Where lightning arresters are used, manufacturer's instructions should be followed.

5.3 Maintenance of Combination Motor Controllers After a Fault Condition

See Annex A.

6 Service and Storage Conditions

See ICS 1, Clause 6.

7 Construction

7.1 Components of Combination Motor Controllers

7.1.1 General

A combination motor controller shall consist of an externally operable circuit-disconnecting means and a magnetic motor controller mounted in a single enclosure. The motor controller shall include motor and branch-circuit overload

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controller shall include motor and branch-circuit overload protection unless equivalent protection is otherwise provided. Where required by the particular application, a circuit breaker (serving also as an externally operable disconnecting means) or provision for fuses shall be included for protection against overcurrent due to short circuits or ground faults.

7.1.2 Manually Operated Disconnect Switches in Combination Motor Controllers

For a combination motor controller rated 100 horsepower or less, the switch shall be a motor-circuit switch having a horsepower rating as great as the horsepower rating of the combination motor controller at the rated voltage.

For a combination motor controller rated more than 100 horsepower, the switch need not be a motor-circuit switch, but it shall be capable of interrupting the maximum operating overload current of a motor of the same horsepower rating as that of the combination motor controller at the rated voltage.

7.1.3 Circuit Breakers in Combination Motor Controllers

Circuit breakers in combination motor controllers shall be either of the inverse-time or the instantaneous-trip magnetic type.

The combination motor controller which includes an instantaneous-trip circuit breaker, is considered an integral unit and is assigned an interrupting rating by the controller manufacturer.

7.1.4 Clearance and Creepage Distances for Disconnecting Means Suitable for Service Equipment

Clearance and creepage distances for disconnecting means and the line side of short-circuit protective devices of combination controllers, where such disconnecting means or short-circuit protective devices, or both, are used as service entrance equipment, shall be in accordance with Table 6-7-1.

These clearances do not apply to the internal spacings of circuit breakers and interrupters which are designed to the applicable standards of Underwriters Laboratories Inc.

7.2 Enclosures

7.2.1 Combinations of Units

The types of combination motor controllers listed in Clause 3 shall be permitted to exist in single enclosures or as combination units in motor control centers, switchboards, busway plug-in devices and panelboards.

7.2.2 Interlocking of Combination Motor Controller Doors

Enclosures of combination motor controllers shall be equipped with a hinged door which is firmly held in place and interlocked with its associated disconnecting means so that the door cannot be opened without first opening the disconnecting means.

Means shall be provided for locking the disconnecting means in the open position when the door is closed.

Where required by the particular application, a deactivating means (defeater) shall be provided to permit entry into the enclosure when the disconnecting means is closed.

7.3 AC Automatic Combination Oil Field Controllers

7.3.1 Disconnecting Means

Each controller shall be provided with a motor-circuit switch* or circuit breaker which can be opened under load to isolate the circuit.

*Where required by the particular application, the switch should meet the requirements for service entrance equipment. See 7.1.4.

7.3.2 Wiring Diagrams

Wiring diagrams shall be attached to or placed in a pocket of the controller enclosure.

7.3.3 Short-Circuit Protection

Each controller shall be provided with a circuit breaker or provision for fuses of appropriate size to protect the motor branch circuit against overcurrent due to short circuits or ground faults.

Table 6-7-1
CLEARANCE AND CREEPAGE DISTANCES OF DISCONNECTING MEANS SUITABLE FOR SERVICE EQUIPMENT

Voltage Between Parts Involved, Volts	Minimum Spacing, Inches			
	Between Uninsulated Live Metal Parts of Opposite Polarity		Between Uninsulated Live Metal Parts and Any Grounded Dead Metal	
	Over Surface	Through Air	Over Surface	Through Air
0-125	3/4	1/2	1/2	1/2
126-250	1-1/4	3/4	1/2	1/2
251-600	2	1	1	1/2

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7.3.4 Lightning Arresters

Lightning arresters connected to the line side of the disconnecting means shall be provided for all phases in each controller.

7.3.5 Contactors

Each controller shall be provided with a three-pole magnetic contactor.

7.3.6 Undervoltage Release

Each controller shall be provided with undervoltage release.

7.3.7 Starting Open-Phase Protection

Each controller shall be provided with starting open-phase protection.

7.3.8 Overload Protection

Each controller shall be provided with three overload relays, unless equivalent protection of the motor is otherwise provided. The overload relays, or equivalent protection, if located in the controller or operating through the controller, shall be manually reset.

7.3.9 Program Timer

Where required by the particular application, a program time switch shall be provided with a 24-hour dial, having a minimum ON interval of not more than 15 minutes and minimum OFF interval of not more than 30 minutes. A day omission feature shall be provided where required by the particular application.

7.3.10 Sequence Starting Provision

Where required by the particular application, the controller shall be provided with a means of delaying starting after power restoration, following a power failure. This feature is intended to prevent multiple simultaneous starting and permits normal voltage recovery before starting the motor.

7.3.11 Selector Switch

Each controller shall include a three-position selector switch marked HAND-OFF-AUTO to permit a choice of manually controlled operation or automatic operation.

7.3.12 Grounding Provision

A grounding stud, 1/4 inch (6 mm) diameter or larger, or lug shall be provided on each enclosure.

7.3.13 Enclosure

Each controller shall be enclosed in an enclosure that is suitable for outdoor applications and equipped with a threaded conduit hub at the top and knockouts at the bottom. See ICS 6. Where ventilating louvers are provided, the openings shall be protected by a mesh screen having a wire gauge in the range of 14 to 18 AWG, or the equivalent.

Each controller shall have provision for mounting either on a flat surface or on a pole.

7.3.14 Overload Relay Current Element Table

Where overload relays are provided, an overload relay current element selection table shall be attached to the enclosure. This table shall be based on operation in the sun at an ambient temperature of 40°C, as measured by a shaded thermometer.

7.4 AC Automatic Combination Irrigation Pump Controllers

7.4.1 Disconnecting Means

Each controller shall be provided with an externally operable motor-circuit switch* or circuit breaker which may be opened under load to disconnect the motor and control from the power source.

*Where required by the particular application, the switch should meet the requirements for service entrance equipment. See 7.1.4.

7.4.2 Wiring Diagrams

Wiring diagrams shall be attached to or placed in a pocket of the controller enclosure.

7.4.3 Short-Circuit and Ground-Fault Protection

Each controller shall be provided with a circuit breaker or provisions for fuses of appropriate size to protect the motor branch circuit against overcurrent due to short circuits or ground faults.

7.4.4 Overload Protection

Each controller shall be provided with three overload relays unless equivalent protection of the motor is otherwise provided.

7.4.5 Overload Relay Current Element Table

Where overload relays using interchangeable current elements are provided, an element selection table shall be attached to the enclosure.

7.4.6 Control Circuit

The control circuit shall provide the necessary connections for either three-wire or two-wire control. There shall be mounted on the enclosure a three-position selector switch to provide for manual or automatic operation, and an OFF position.

7.4.7 Grounding Provision

A grounding stud, 1/4 inch (6 mm) diameter or larger, or lug shall be provided on each enclosure.

7.4.8 Enclosure

Each controller shall be enclosed in an enclosure which is suitable for outdoor applications and equipped with a threaded conduit hub at the top and knockouts at the bottom. See ICS 6. Where ventilation is required, the openings shall be so protected as not to permit rain to reach live parts.

The enclosure shall be provided with a hinged door, interlocked with the disconnecting means. There shall be

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provision for locking this door. Where required by the particular application, space shall be provided in the enclosure for essential optional equipment, such as pressure switch, back-spin timer, and lightning arresters.

Each controller shall have provision for mounting either on a flat surface or on a pole.

8 Performance Requirements and Tests

8.1 Design Test for Short-Circuit Current Ratings for Combination Controllers

Selected combination motor controllers which include short-circuit protection shall be tested to verify the ability of the overcurrent devices and other components which may be involved, such as disconnect devices (including operating mechanisms), starters, wiring and enclosures, to withstand short circuits.

Combination motor controllers shall be evaluated and marked in accordance with UL 508.

Manufacturers may determine that their designs meet the standard performance criteria by test or by a combination of test and calculation or interpolation.

9 Application

See Clause 9.4 of Part 2 and Annex B.

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Part 7
MAGNETIC LIGHTING CONTACTORS

1 General

1.1 Scope

The standards in this part apply to alternating-current contactors, rated 600 volts or less, designed for the control of tungsten lamp and electric discharge lighting loads.

1.2 Normative References

NEMA Standards Publication No. 250, ICS 1 and ICS 2, Parts 1 and 2 apply to this part unless otherwise stated.

2 Definitions

See ICS 1, Clause 2.

3 Classification

This part contains no classifications.

4 Characteristics and Ratings

The maximum continuous current rating, open or enclosed, when the load is connected directly to the load terminals of the contactor, shall be 30, 60, 75, 100, 150, 200, 225, 300, 400 or 600 amperes.

Where magnetic lighting contactors are used as switching elements to control the primaries of transformers supplying lighting loads, the continuous current rating shall be reduced as follows:

a. For transformers having inrush currents (worst case peak) not more than 20 times the peak continuous current rating—derate to 50 percent

b. For transformers having inrush currents (worst case peak) over 20 but not more than 40 times the peak continuous current rating—derate to 25 percent

5 Product Marking, Installation and Maintenance Information

See ICS 1.3 for preventive maintenance instructions.

6 Service and Storage Conditions

See ICS 1, Clause 6.

7 Construction

See ICS 1, Clause 7.

8 Performance Requirements and Tests

8.1 Design Tests

All of the test and performance requirements of Parts 1 and 2, except the make and break design test, shall apply to magnetic lighting contactors.

Magnetic lighting contactors shall be capable of meeting the requirements for the overload and endurance tests as given in UL 508.

8.2 Short-Time Capability

The short-time capability of a new (unused) magnetic lighting contactor shall be 15 times its continuous current rating for 1/2 second. See Part 1, Clause 8 for test procedure.

9 Applications

There is no application information in this part.

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Annex A
(Informative)
MAINTENANCE OF MOTOR CONTROLLERS AFTER A FAULT CONDITION

A.1 Introduction

In a motor branch circuit which has been properly installed, coordinated and in service prior to the fault, opening of the branch-circuit short-circuit protective device (fuse, circuit breaker, motor short-circuit protector, etc.) indicates a fault condition in excess of operating overload. This fault condition should be corrected and the necessary repairs or replacements made before reenergizing the branch circuit.

It is recommended that the following general procedures be observed by qualified personnel in the inspection and repair of the motor controller involved in the fault. Manufacturers' service instructions should also be consulted for additional details.

The following are procedures to be followed in order to return to service a motor controller which has been subjected to a short circuit or a ground fault. These procedures are not intended to cover other elements of the branch circuit, such as wiring and motors, which may also require attention.

A.2 Procedures

DANGER—all inspections and tests are to be made on controllers and equipment which are deenergized, disconnected, locked out and tagged so that accidental contact cannot be made with live parts and so that all plant safety procedures will be observed.

A.2.1 Enclosure

Where substantial damage to the enclosure, such as deformation, displacement of parts or burning has occurred, replace the entire controller.

A.2.2 Disconnect Devices

A.2.2.1 Circuit Breakers

Examine the enclosure interior and the circuit breaker for evidence of possible damage. If evidence of damage is not apparent, the circuit breaker may be reset. If there is any indication that the circuit breaker has opened several short-circuit faults, or if signs of possible deterioration appear either within the enclosure or on the circuit breakers, for example, surface discoloration, insulation cracking, or unusual toggle operation, replace the circuit breaker.

A.2.2.2 Disconnect Switch

Verify that the external operating handle is capable of opening the switch. If the handle fails to open the switch or if visual inspection after opening indicates deterioration beyond normal wear and tear, such as overheating, contact blade or jaw pitting, insulation breakage or charring, replace the switch.

A.2.2.3 Fuse Holders

Where deterioration of fuse holders or their insulating mounts has occurred replace them.

A.2.3 Terminals and Internal Conductors

Where there are indications of arcing damage or overheating, or both, such as discoloration and melting of insulation, replace the damaged parts.

A.2.4 Motor Starter

A.2.4.1 Contactor

Replace contacts showing heat damage, displacement of metal, or loss of adequate wear allowance of the contacts, and also replace the contact springs where applicable. If deterioration extends beyond the contacts, such as binding in the guides or evidence of insulation damage, replace the damaged parts or the entire contactor.

A.2.4.2 Overload Relays

a. If burnout of the current element of an overload relay has occurred, replace the complete overload relay. Any indication that an arc has struck or any indication of burning of the insulation of the overload relay, or both, also requires replacement of the overload relay.
b. If there is no visual indication of damage that would require replacement of the overload relay, trip the relay electrically or mechanically to verify the proper functioning of the overload relay contact(s).
c. If there is no visual indication of damage that would require replacement of an overload relay with solid-state output, check the overload relay output to verify performance within the minimum and maximum current ratings.

A.2.5 Return to Service

Before returning the controller to service, check for the tightness of electrical connections and for the absence of short circuits, ground faults and leakage current.

Close and secure all equipment enclosures before the branch circuit is energized.

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Supplement 1

SCOPE OF THE INDUSTRIAL CONTROL AND SYSTEMS SECTION

The NEMA Standards Publications for Industrial Control and Systems cover the requirements for all industrial control apparatus except as modified below. These standards cover all devices, whether electric, magnetic, mechanical, or electronic (except those devices intended specifically for marine auxiliaries and propulsion control apparatus, mine locomotive control apparatus, and railway and railroad locomotion) which, individually or grouped, serve to govern in some predetermined manner the electric power delivered to the apparatus to which they are connected, and which are intended to function on commercial voltages of 750 volts or less, DC and 7,200 volts or less, AC.

Industrial Control and Systems Section equipment comprises, but is not limited to, mechanical, electromechanical and solid-state devices, components, and controls.

The equipment is principally used in industrial applications for the control or regulation, or both, of power utilization apparatus, including motors. Such equipment is rated not more than 750 volts DC or 7,200 volts AC.

These devices, components, and controls may be arranged to include one or more feedback loops. Functional elements in such arrangements include sensors, programmable controllers, operational amplifiers, encoders, tape readers, gauging equipment and computer elements. Computer elements for the readout, logging, processing, and programming input and monitoring output of data may or may not be in the feedback loop. Devices, components and controls so arranged are used in functions such as:

a. Computer control of machines
b. Industrial process regulation
c. Integrated mill control
d. Energy management
e. Emergency and standby power control
f. Control of the cogeneration of electric power

The Industrial Control and Systems Section scope specifically includes, but is not limited to, products principally used to:

a. start, stop, protect, accelerate, decelerate, reverse, or control the speed of electric motors
b. automatically disconnect, connect, or transfer all classes of loads fed by primary or alternate power sources
c. provide some mechanical movement through the action of magnets or solenoids
d. start, stop and control AC or DC adjustable speed drives, whether unregulated, regulated, or automatically regulated, including semiconductor power converters and invertors for adjustable speed drives, and providing such functions as: regulating speed, tension, current, frequency and voltage
e. start, stop and control the function and operation of machine tools, including feedback control and speed, position and torque
f. start, stop and control the operation of automatic warehouses, including control of conveyors, stackers, and the like
g. start, stop and control the operation of cranes and hoists
h. start, stop and control the operation of AC motors applied to fans, pumps, and blowers, including provision for feedback control of speed by sensors such as for temperature, flow, and pressure
i. control the management of energy under normal and emergency conditions including peak load shaving
j. control generator equipment used in dispersed power generation systems for cogeneration, emergency, or stand-by electric power

Also included, but not limited to, are:

a. Motor controllers
b. Motor control centers
c. Medium-voltage controllers
d. Programs and related documentation making up the software that is furnished with programmable devices for industrial control and systems equipment
e. Register and synchronizing controls
f. Digital display devices
g. Analog-digital convertors and transducers
h. Programmable controllers
i. Functional elements of systems, such as:
    1. Operational amplifiers
    2. Computer elements
    3. Encoders
    4. Tape readers
    5. Sensors
    6. Man-machine interface devices
    7. Gauging equipment
j. Renewal parts for Industrial Control and System products.

Examples of Industrial Control and System products are:

a. Manual, magnetic and solid-state (static) starters and controllers
b. Relays and contactors
c. Automatic transfer switches and controllers, and associated by-pass isolation switches
d. Drum switches
e. Overload devices intended primarily for the starting and running protection of electric motors, including inherent overload protective devices
f. Rheostats and resistors
g. Autotransformers and reactors of the type principally used in reduced-voltage starters

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h. Control-circuit and pilot devices including, but not limited to, timers, pushbuttons, indicating (pilot) lights, solenoids, photoelectric relays, and plugging switches, speed switches, domestic water pump pressure switches
i. Limit, pressure, vacuum, temperature and liquid-level switches.
j. AC and DC brakes, clutches, and electrical operators
k. Resistance dimmers, autotransformer dimmers, reactor dimmers, and solid-state (static) dimmer systems
l. Solid-state logic devices
m. Control panels for machine tool and similar machines
n. Terminal blocks of the molded barrier or sectional type and terminal strips used for the connection of conductors, electrical and electronic circuits and equipment. These include, but are not limited to, terminal blocks using wire binding screws, pressure wire connectors, stud and nut, quick connect, solder lug, and solderless wrapped terminations, and terminal blocks which incorporate fuse holders, test/disconnect features, indicator lamps, diodes, etc.
o. Automatically regulated adjustable speed drive systems such as: rolling mill drives, paper mill drives, slasher drives

Exclusions:

Excluded from the product scope are:

a. Specific components and systems covered by the product scopes of other NEMA sections
b. Automatic and manual temperature and humidity controls and panels that are in the scope of the Residential Controls Section of the types principally used in air conditioning, refrigeration, and comfort heating of nonindustrial areas
c. Motors, generators and motor-generators, which function as control when constituting part of adjustable speed drives

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NEMA STANDARDIZATION BACKGROUND

The purpose of NEMA standards, their classification, and status are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for their particular needs. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process, or procedure with reference to one or more of the following: nomenclature, composition, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Standardization Policies and Procedures, p. 1)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the Standards Publication may be capable of otherwise equivalent performance.

(Standardization Policies and Procedures, p. 6)

Categories of Standards

National Electrical Manufacturers Association Standards are of three classes, which have received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative:

1. NEMA Standard, which relates to a product, process, or procedure commercially standardized and subject to repetitive manufacture.
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development.
3. Adoptive Standard, which is adopted in whole or in part from the standards of another organization, either domestic, regional, or international.

(Standardization Policies and Procedures, pp. 5)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative.

(Standardization Policies and Procedures, pp. 5)

Identification of Status

Standards in NEMA Standards Publications are identified as "NEMA Standard," "Suggested Standard for Future Design," or "Adoptive Standard." These indicate the status of the standard. A statement incorporating the auxiliary verb "shall" indicates that compliance with a requirement is mandatory for compliance with the standard. These classes of standards are identified in the foreword or throughout the text.

The material identified as "Authorized Engineering Information" is designated similarly. Statements incorporating other auxiliary verbs such as "should," "may," etc. refer to the authorized engineering information and not to procedures required for compliance with the standard.

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Killark-Stahl, Inc.
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Klockner Moeller Corporation
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